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CONTENTS

	Page
The Use of Rotenone for Management of New York Trout Waters—ROBERT G. ZILLIOX and MARTIN PFEIFFER	3
Use of Fish Toxicants in the Province of Quebec—GUSTAVE PRÉVOST	13
Three Years' Use of Toxaphene as a Fish Toxicant in British Columbia—GEORGE E. STRINGER and ROBERT G. McMYNN	37
Observations on the Standing Trout Populations and Experimental Plantings in Two Ontario Streams—H. R. McCRIMMON	45
Fisheries Management Development Projects—WILHELM EINSELE, translated by D. S. RAWSON	57

Editor's Note: The first three articles in this issue were papers presented at a symposium on "Fish Toxicants as a Tool in Fishery Management," conducted in Ottawa on January 8, 1960, at the thirteenth meeting of the Canadian Committee on Freshwater Fisheries Research, under the sponsorship of the Fisheries Research Board of Canada. A fourth paper, "The Development of Selective Toxicants for Sea Lamprey Control," by B. G. H. Johnson, Fisheries Research Board of Canada, Biological Station, London, Ont., is to be published elsewhere under the auspices of the Great Lakes Fishery Commission.

The article "Fisheries Management Development Projects," by Dr. W. Einsele, is the translation of a section of the booklet "Lakes, Rivers and Brooks in Salzkammergut, Austria," published by the Austrian Government for the Fourteenth International Limnological Congress, August, 1959.

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Correspondence should be addressed to the DIRECTOR, INFORMATION AND EDUCATIONAL SERVICE, DEPARTMENT OF FISHERIES, OTTAWA, CANADA.

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of
HON. J. ANGUS MACLEAN, M.P.,
Minister of Fisheries

The Use of Rotenone for Management of New York Trout Waters

by

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and

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Introduction

Over 100 lakes and ponds have been reclaimed in New York State since 1950. With few exceptions these waters are located in the Adirondack region of northern New York which contains approximately 2000 lakes and ponds about 8900 square miles in area. Its waters, ranging in size from small bog ponds of less than an acre to 30-mile-long Lake George, are generally cold, infertile, unproductive bodies of water best suited for producing the native brook trout and lake trout. In 1950 rotenone powder, rotenone wettable paste, emulsifiable rotenone 5 per cent and Fishtox were employed in the reclamation programme. Since 1951 emulsifiable rotenone five per cent or emulsifiable synergized rotenone 2.5 per cent have been used. Although the emulsifiable product is more expensive than the non-liquid products, the ease of handling, transportation and application of the liquid product narrows the price differential.

In the Adirondacks two native gamefish species predominated the area: the lake trout and brook trout. The so-called warm water game and pan fish species (other than sunfish) were not native to the region. Native associates of the lake trout and brook trout in the Adirondacks vary from watershed to watershed; but the most common association is the brown bullhead, pumpkinseed, white sucker and horned dace. Less frequently are found the fine-scaled sucker, round whitefish and several species of minnows. Over the past 75 years and mainly in the last 40 years a tremendous change in the fish fauna has taken place. Through misguided stocking, bait pail dumping and invasion from one water in a chain to other waters, there are at present no lakes or ponds open to public fishing, located along roads, that retain their native fish population. Greater than 90 per cent of the total water area in parts of the Adirondacks has been subject to warm water game and panfish introductions, causing a serious decline or elimination of the brook trout fishery and a decline in the lake trout fishery. Many of the smaller waters provide little if any angling for the introduced species due to stunting.

The stocking of hatchery brook trout of various sizes in such waters has given poor returns. In view of the need for reclamation and state ownership of many waters, the Adirondacks has proven to be an excellent region for a sustained reclamation programme. With few exceptions the general public has been very enthusiastic concerning the programme.

Materials and Methods

Equipment

Of 92 waters reclaimed between 1950-1958 only 24 were accessible by motor vehicle. Lightweight but sturdy equipment was necessary for the application of rotenone. Penn Yan cartop boats, weighing approximately 65 pounds with the middle seat removed and fitted with shoulder carrying yokes for transport over trails or through the woods were used for pond work. These boats accommodated a pump, two or three men and up to 25 gallons of rotenone, and were propelled by an outboard motor. The pumps used for spraying were Pacific Marine Pressure Pumpers, Model 5-A-8, weighing about 40 pounds with fittings and carried on pack boards when being transported. A square-stern Adirondack guide boat weighing approximately 65 pounds and equipped with a shoulder carrying yoke, was used for hand pumping swamps, shallow water areas, and for general water transportation.

Application of Rotenone

Emulsifiable rotenone five per cent, a product obtained from several companies, was used at a concentration of approximately 0.5 p.p.m. Emulsifiable synergized rotenone 2.5 per cent, a product of S. B. Penick & Company, was used at a concentration of 0.25 p.p.m. on a number of waters between 1956 and 1958. The method of application insofar as possible was designed to distribute the rotenone equally throughout the pond waters. The pressure pumper, with fire nozzle attached, was used to spray the shoreline area, and a spray bar with eight nozzles, covering a swath approximately 30-40 feet wide, was used to spray the surface. Various lengths of weighted hose were towed behind the boat at various depths of deep pumping. Simultaneously with the pond treatment, another crew treated inlets, outlets, springs and swampy areas, using five gallon fire-fighting hand pumps.

A boat crew could easily treat 50 surface acres per day, including shoreline spraying and deep pumping. In the case of 340 acre St. Regis Pond, the lake was divided into five approximately equal zones and treated on successive days. On some waters two boat crews operating pressure pumps were employed.

Adjuncts of a Reclamation Programme

Barrier Dams

Barrier dams had to be constructed on the outlets of 18 reclaimed waters, in order to prevent reintroduction of undesirable species of fish. These dams are of log crib construction, planked on the upstream surface, with spillways of varying width, depending upon the flow of water. Where possible, barrier dams are designed to provide about a three foot straight fall, with an apron constructed to prevent a deep pool for the "take off" of fish attempting to jump. To build the dam on the best location it is often feasible to locate it considerably downstream from the pond proper (Figure 1).

In watersheds where beaver activity can be expected, site selection is important. Two barrier dams were flooded over in the later years by the erection of beaver dams below the barrier dams. This provides a method of entry into the reclaimed water for those species of fish downstream from the barrier dam, between the barrier and beaver dam.

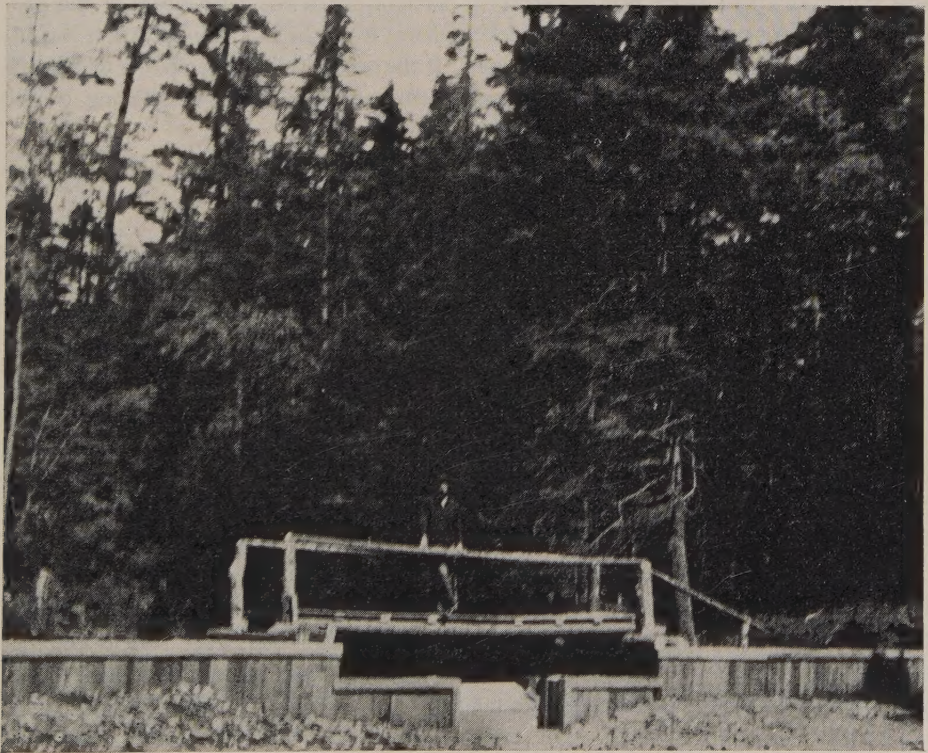


FIGURE 1.—Barrier dam: (above) in process of construction; (below) completed, with trail cat-walk.

Dams built in rock, rubble or gravel type streambeds have functioned perfectly. Those built in sand streambeds have undercut in three instances and cut around the sides in two instances. In two of these five malfunctionings yellow perch reinvaded the reclaimed pond.

Due to the inaccessible nature of the damsite locations, the use of concrete is not feasible in all cases. However, in the more accessible damsite locations, we are now considering the construction of concrete barrier dams. The initial cost of concrete barrier dams will be considerably more, but they can be expected to last longer, require less maintenance and function more effectively than log dams.

Special Legislation

A recognized method of introducing undesirable species of fish into New York waters has been via the minnow or bait bucket. Legislation enacted in 1951 (Section 268, subdivision 9, of the New York State Fish and Game Law) prohibits the use of fish as bait either dead or alive, in reclaimed and other natural brook trout waters in the Adirondack Region. A list of such waters, located by county and township is published annually, and in addition metal warning signs are posted about the ponds. To enhance the effectiveness of this legislation, it has been recommended for 1960 that the possession of bait fish on the shores or waters thereof, shall be considered a violation.

Public Relations

While there is no question concerning the biological justification of our reclamation programme, the use of fish toxicants may cause controversy among the public. Considerable public relations work was undertaken, particularly in the early years of the programme. We continue to contact and seek approval from the local conservation organization interested in the pond to be reclaimed. If the water to be reclaimed is in private ownership, written agreement is obtained, stating approval and guaranteeing public access to the water.

Discussion

Physical and Chemical Characteristics of Reclaimed Waters

Of 90 waters reclaimed between 1950-1958, 69 were less than 50 surface acres in size, averaging 18 acres; 13 were between 50 and 100 surface acres, averaging 62 acres and eight were over 100 surface acres, averaging 162 acres. The largest body of water reclaimed was 340 acres. The water of many of the deeper ponds shows depletion of oxygen in the depths. A typical 30-acre pond of this type having a maximum depth of 55 feet would demonstrate marginal oxygen values at 25 feet and zero oxygen values at 35 feet. Other waters in the 50-60 foot maximum depth range evidenced chemical conditions suitable for fishlife at all depths. The deepest water reclaimed had a maximum depth of 80 feet. Regardless of the depth or chemical conditions in the depths the data indicate the introduced species of fish were eliminated in all instances.

Thirty-two of these waters ranged in pH between 5.4 and 5.9; 53 ranged in pH between 6.0 and 6.9 and seven waters had surface readings of 7.0 or 7.1 with all but one of these seven being acid in the depths. Adirondack waters are poorly buffered and more acid readings could be expected for many of these waters, at a time of the year other than when the reading was taken.

Elevation of these waters ranged from 970 feet to 2065 feet above sea level, with an average elevation of 1620 feet.

Summarization of water temperature data pertaining to 45 waters reclaimed between 1950-1955 is given in Table 1.

TABLE 1
Summary of Water Temperatures for 45 Reclaimed Ponds

Month Reclaimed	Number of Ponds Reclaimed	Water Temperatures in degrees Fahrenheit	
		Surface (range)	Bottom (range)
July.....	7	70-73	47-62
August.....	14	68-74	46-72
September.....	20	60-75	40-67
October.....	4	53-62	45-60

All but four of the waters summarized in Table 1 were thermally stratified at time of reclamation. No relationship was found between water temperature at time of treatment and complete eradication of all species of fish. The general relationship of water temperature and chemistry to time for observed final kill is similar to that given by Zilliox and Pfeiffer (1956) for 14 Adirondack reclaimed waters.

Relative hardness of water (p.p.m. total alkalinity expressed as calcium carbonate) is often considered a general indicator of biological productivity. Table 2 shows the relative hardness for 27 representative waters reclaimed between 1950-1958 and classified according to Juday, (1942).

TABLE 2
Relative hardness for 27 waters reclaimed between 1950-1958

Total Number of Waters	Classification				
	0-5 p.p.m.	5-10 p.p.m.	10-20 p.p.m.	20-30 p.p.m.	over 30 p.p.m.
27	5	12	8	2	0

Total dissolved solids values are available for five reclaimed waters. These five waters are rather typical in chemical and physical characteristics to many waters reclaimed to date. The five waters include two ponds having no inlet or outlet:—26.1 and 16.9 p.p.m. total dissolved solids; one water with an inlet but no outlet:—26.2 p.p.m. total dissolved solids; one water with no inlet but having an intermittent outlet:—22.9 p.p.m. total dissolved solids; and one water with a permanent inlet and outlet:—26.3 p.p.m. total dissolved solids.

Approximately half of the waters treated had been subjected to varying degrees of beaver activity (Figure 2). Beaver dams on the pond outlet or tributary streams resulted in acre-feet of impounded, shallow, swampy water or floating bog type of



FIGURE 2.—Portion of drained beaver impoundment.

environment. Considerable time and labour was expended in draining beaver impoundments. (Zilliox and Pfeiffer, 1956, p. 182).

Muskrat and beaver activity caused underground channels in flooded bog or floating bogs, and springs or spring seepage entered some of these passages. The possibility exists that fish or fish eggs could be harbored in such channels until water in portions of the pond proper became detoxified. Although the introduced non-native species of game and pan fish have been eliminated in heavily beavered waters, it has not been possible to eliminate all native species in any such waters.

Duration of Toxicity

Toxicity checks were made using live hatchery fingerling or yearling brook trout in wire cages suspended at various depths in 75 waters reclaimed between 1950-1957. Two cages of test fish placed at different locations and depths in the pond were used. A 48-hour suspension period was deemed sufficient to give a reliable index of toxicity. Care was observed in making the toxicity tests, so that the cages were neither suspended at a depth having unsatisfactory chemical conditions for brook trout, nor resting on pond bottom in possible rotenone residue.

In all cases where test fish indicated that waters had become detoxified, no losses of trout occurred when stocking ensued. Toxicity data from these waters indicate that in all but a few waters, ponds treated in the fall of the year can be expected to become

non-toxic to brook trout the following spring. Most waters became detoxified in less than 100 days following treatment. Occasional ponds will remain toxic to brook trout for longer periods of time. Ponds with little or no inlet or outlet flow remain toxic longer than ponds with such flowage. Five such waters remained toxic to brook trout over 150 days. One bog pond lacking an outlet and treated at a concentration of 2.0 p.p.m. remained toxic for at least 293 days.

When stocking a pond that has a flowing outlet the year following reclamation, it has been judged unnecessary to conduct a toxicity check. Toxicity checks are still conducted on waters having no outlet or an impermanent outlet.

Siegler and Pillsbury (1947) reporting for New Hampshire waters found that toxic conditions for brook trout endured from less than 35 days to more than 137 days following treatment. Waters were treated with derris (3.70-4.55 per cent rotenone) at concentrations varying between 0.5 p.p.m. and 2.0 p.p.m. Toxicity data for New Hampshire waters is also similar to Adirondack waters when emulsifiable rotenone five per cent is used at comparable concentrations (R. Knowlton, State of New Hampshire Fish and Game Department, personal communication).

Clemens and Martin (1953) reporting for two Oklahoma waters with a pH of 6.8 and 6.7, using emulsifiable rotenone at concentrations of 0.5 and 1.0 p.p.m. respectively, found detoxification occurring less than 94 hours following treatment. In clear alkaline ponds (pH 7.7-8.8) using emulsifiable rotenone at concentrations varying between 1.0 p.p.m. and 2.0 p.p.m., detoxification occurred in less than 56 hours. Surface temperatures varied between 78.2 and 91.6 degrees Fahrenheit and minnows were test fish used. The rapidity of loss of toxicity in such waters can be considered undesirable. It is possible detoxification can occur in certain areas of the lake or pond treated, prior to complete mixing in the pond proper.

Success of Programme

The yellow perch is the most prevalent introduced species of fish in Adirondack waters and the introduced fish most frequently encountered in waters to be reclaimed. The incidence of various introduced species in 90 waters prior to reclamation was as follows: yellow perch 75; smallmouth bass 14; northern pike 12; chain pickerel 6; largemouth bass 2; black crappie 2; rock bass 2; pikeperch 1; carp 1. Various combinations of the above named species were encountered in many of the individual ponds.

Our data to date indicate that in every water reclaimed with rotenone, the above listed species have been completely eradicated. Three native species, lake trout, brook trout, and common whitefish have been eradicated in all ponds when present.

The success of a reclamation programme should be measured in terms of quality of fishing produced rather than in terms of complete eradication of all fishlife. We have learned from past experience that the presence of yellow perch and other introduced species usually makes it impossible to sustain a successful brook trout fishery even with legal-sized stocking. Therefore, it is imperative that these species be completely eliminated. Emulsifiable rotenone five per cent used at 0.5 p.p.m. and emulsifiable synergized rotenone 2.5 per cent used at 0.25 p.p.m. will accomplish this in Adirondack waters.

Our data also indicate that a typical brook trout pond will produce a greater poundage of brook trout if native species are eliminated and only brook trout are present. Unfortunately, we have not been able to successfully eliminate all native species of fish in these waters.

Zilliox and Pfeiffer (1956), gave the following criteria for a complete kill: "Failure of observation, angling and netting for two successive years following reclamation to indicate any species of fish present in a reclaimed pond, except stocked trout, would appear to be a reasonable indication of a complete kill". These criteria continue to hold true for the non-native species previously mentioned, but do not hold true for native species. For example, a water reclaimed in 1953 and judged to be a complete success in 1955 provided angling for the brown bullhead and pumpkinseed in 1959. Similarly 12 of 23 ponds reclaimed during 1950, 1951 and 1952 were judged to be complete successes in 1954; six of the 12 now contain either the brown bullhead, white sucker or a native species of minnow. Although we are aware that some reclaimed waters have been subjected to introductions by anglers, the data indicate that for most of the waters concerned the native species survived reclamation.

The synergized rotenone product has not proven superior to the non-synergized product in the matter of eliminating native species of fish.

Burdick, Dean and Harris (1955) showed that under laboratory conditions creek chubs were killed between 51-106 minutes using emulsifiable rotenone at a concentration of 0.5 p.p.m. The survival of this species in a number of reclaimed waters would indicate that concentrations of 0.5 p.p.m. are not penetrating to all portions of the water treated. These workers also show that the smallmouth bass has a greater resistance to rotenone than does the creek chub. As the smallmouth bass have been successfully eliminated in all 14 waters where present prior to treatment, it would appear the habits of a species of fish in its natural environment enable it to survive reclamation.

Five waters reclaimed between 1950-1954 had populations of brook trout infested with copepod parasites (*Salmincola* sp.). One of these waters was reclaimed with Fishtox, the remaining four with emulsifiable rotenone. To date the trout in these waters remain free from infestation. It is possible only brook trout have to be successfully eliminated to break the cycle of this ectoparasite, inasmuch as native species survived reclamation in three of the five waters concerned.

Management of Reclaimed Waters

All reclaimed waters in the Adirondacks are managed for salmonids and with few exceptions with brook trout. None have been managed for lake trout, although suitable conditions exist for this species in many of the waters. Primary reason for managing for brook trout are: 1) brook trout provide greater fishing opportunity to a larger number of anglers; 2) brook trout provide angling the year following reclamation; 3) brook trout require little in the line of management techniques other than annual stocking.

For variety to the angler and study purposes, the splake (M brook trout x Flake trout) and the rainbow trout are being stocked in nine waters.

Although rainbow trout do not grow or survive well in all Adirondack waters, they have been stocked in certain waters and have proved successful. The pH of the water is the only evident factor pointing towards success or failure of this species.

A water with a pH lower than 6.2 will generally not prove favourable for rainbow trout. Horseshoe Pond, a 90-acre, 30-foot maximum depth water with a pH of 6.9 will produce rainbow trout in the four- to five-pound class. Black Pond, a 25-acre, 50-foot maximum depth pond, with a varying pH between 4.8 and 5.4 has failed to produce any rainbow trout after three years of stocking, but maintains a fair brook trout population.

The splake has been stocked in several waters having varied environments. In a typical small brook trout pond of 10 acres, having a maximum depth of 22 feet, where all species of fish were eliminated, splake have not attained a length greater than 12-14 inches. In a larger, deeper water where minnows and suckers have survived reclamation, splake have attained a size of 17 inches. Splake in their fifth growing season have attained weights in excess of five pounds in a non-reclaimed Adirondack water containing forage fish. In one water where the splake has been stocked in combination with rainbow trout, adults of the alewife were introduced in 1958 and 1959. They spawned successfully in 1959 and a good crop of young of the year are present. It is thought that the alewife will provide forage for the splake, resulting in an increase in the growth rate of splake in this water.

Brook trout do well in reclaimed waters. Growth and survival studies in many of the reclaimed ponds and lakes indicate that the number of trout stocked per surface acre, the presence or absence of competitive species of fish and the chemical quality of the water are factors affecting growth and survival.

Growth data also indicate that rotenone products used at 0.5 p.p.m. do not have an adverse residual effect upon the food supply of brook trout in New York waters. The growth rate of brook trout fall fingerlings stocked the year following treatment is as good or better than trout stocked in comparable non-reclaimed waters. The growth rate for fall fingerling brook trout stocked the same year following treatment can be considered normal. Cushing and Olive (1957), using derris powder (five per cent rotenone) at a concentration of 1.0 p.p.m. in a Colorado Reservoir found only short-lived effects to the macroscopic bottom fauna.

Natural reproduction of brook trout is non-existent in many waters and where it does occur in the ponds and lakes studied, it is not sufficient to provide remunerative angling, hence stocking is undertaken. Most of the waters are stocked by airplane and stocking rates between 50-100 fall fingerlings per surface acre of water have been found suitable. Rates in excess of 100 fall fingerlings per surface acre will often result in slow growth and stunting.

Very few stocked fingerling hatchery brook trout older than three winters have been collected in the reclaimed pond studies. Since Adirondack ponds with wild stocks of brook trout will produce four or five winter trout, it appears that the hatchery product is relatively short-lived, even when stocked in reclaimed waters where reclamation has been complete.

We have not engaged in selective or partial reclamation in New York. When managing waters for trout species it seems advisable to try for the complete kill.

A factor affecting production of warm water game fish in New York's waters is competition from rock bass, sunfish, yellow perch and other species. We have not been able to selectively remove these competitive species of fish by use of rotenone. Hence with the exception of farm ponds, rotenone has not been widely employed in managing warm water species in New York.

Comparisons

Many factors could be listed when describing an ideal fish toxicant. If rotenone could consistently eliminate native species of fish and was less costly it could be considered the ideal fish toxicant for New York waters. Because of these limitations it is imperative to experiment with fish toxicants other than rotenone as they become available. In 1958 and 1959 emulsifiable Toxaphene has been utilized in the reclamation of eight ponds. Toxaphene has been used in waters where rotenone has failed to give a complete kill and in waters where we would not expect rotenone to eliminate native species. Toxaphene is less costly than rotenone. It will be several years before we know the capabilities or limitations of Toxaphene. Emulsifiable DDT and emulsifiable Thiodan were also used during 1958 in three ponds.

Conclusion

Rotenone products have been used in the reclamation of many New York waters at a concentration of approximately 0.5 p.p.m. Prior to reclamation, due to the presence of introduced non-native species of fish, these waters provided little if any angling. Annual stocking, with fingerling trout, following treatment, provides remunerative trout fishing in most instances. Complete eradication of the introduced species of fish described, in natural lakes and ponds of New York, is almost a certainty by use of emulsifiable rotenone at a concentration of 0.5 p.p.m. The complete eradication of certain native species of fish is not a certainty. Although it is desirable to eliminate all species of fish, the eradication of the introduced species can be considered sound fisheries management.

Due to the relatively rapid loss of toxicity, the knowledge of its capabilities, its acceptance by the general public, health authorities and fishery administrators, the use of rotenone as a fish toxicant can be expected to continue even as other more efficient and less costly products become available. Certain waters in New York will probably continue to be treated with rotenone products in the near future due to their location, conflicts with riparian rights and possible involvement with human water supply sources.

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Use of Fish Toxicants in the Province of Quebec

by

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Abstract

Rotenone is a fish toxicant used since 1934 but Toxaphene, Endrin and Thiodan, relative newcomers in the field, are the ones mainly studied, first in the laboratory and then in the lakes. A standard method for laboratory work is stressed. Source and ontogenesis of the fish, temperature and volume of the water have a definite effect on the results obtained. In treating natural waters, many factors have to be cared for, e.g. thermocline, weed beds, floating islands, springs, temperature, turbidity, alkalinity of the water, source of the stream. Rotenone has very little effect on food organisms, while Toxaphene has a very prejudicial one, though some species of plankton are more resistant than fish. Toxicity of the water can be checked in the laboratory or in the lake, but no practical method of accelerating detoxification has been worked out yet, although bentonite gives hope. Health hazards are very small. Stocking with speckled trout gives spectacular results in lakes poisoned with Rotenone, but with the other toxicants, delay in the fishing can be long and no definite fishing results have been found or published. Rotenone is still the best product to use but it is very costly, compared with the others.

Table of Contents

	PAGE
Introduction	16
Toxicants used	16
1—Rotenone	17
2—Toxaphene	17
3—Endrin	18
4—Thiodan	18
In the laboratory	18
General Procedure	18
Standard method	18
Study of some factors	19
Source of the fish	19
Size and Ontogenesis	20
Duration of the experiment and symptoms	20
Volume of solution	21
Temperature of the water	22
In Natural waters	22
Prerequisite	22
(1) Upper waters	22
(2) Outlet	23
Application of the toxicants	24
(A) In still waters	24
(a) General Procedure	24
(1) Open Drum + Gasoline pump + Outboard motor	24
(2) Loose Knitted bag	24
(3) Direct from the original container	24
(b) Factors to be considered	24
(1) Thermocline	24
(2) Weed beds	24
(3) Floating Islands	25
(4) Springs at the bottom	25
(5) Mud bottom	25
(6) Temperature	25
(7) Turbidity	25
(8) Alkalinity of the water	25
(9) Other factors	25

	PAGE
(B) In streams.....	25
(a) General Procedure.....	26
(1) Loose knitted bag.....	26
(2) Open drum + Gasoline motor + Pump.....	26
(3) Direct from the container.....	26
(4) Briquettes.....	26
(b) Factors to be considered.....	26
(1) Marsh weedbed.....	26
(2) Source of the stream.....	26
(3) Small isolated holes of water.....	26
(4) Use of two kinds of toxicants.....	26
Effects on aquatic animals other than fish.....	27
(a) In the laboratory.....	27
Quantitatively.....	27
(b) In a lake.....	28
(1) Quantitatively.....	28
(2) Qualitatively.....	28
Verification of toxicity of the water.....	29
Detoxification.....	30
Health Hazards.....	31
Restocking.....	32
Fishing Results.....	32
(a) The quickest results and the most expensive procedure with Rotenone.....	32
(1) Without stopping of fishing.....	32
(2) With a brief stopping of fishing.....	33
(b) Quick results at a reasonable cost with Rotenone.....	33
Fishing stopped for a year or two summers.....	33
(c) Slow results at a very low cost.....	33
Fishing stopped for some years.....	33
(d) Unknown results at a very low cost.....	33
Conclusion.....	33

Introduction

It has been demonstrated on many occasions, scientifically and simply by plain observation, that undesirable fish in too great abundance in a lake are disastrous for the development of, for instance, speckled trout, and therefore should be destroyed.

In our waters we have, by descending order of nuisance: perch, sunfish, carp, catfish, suckers, ling, many species of minnows and even black bass and pike, when they are too small. As a matter of fact, in general, in our type of lakes at least, speckled trout thrive when they are the only species present.

Attempts to remove coarse fish with fishing gears or by other physical methods have generally been unsuccessful; even the drainage of a farm pond, unless there is complete drying-out, generally fails to remove all the fish. Partial removal of coarse fish could sometimes bring improvement, but the results are usually only temporary since most of these coarse fish are very prolific and the lake will resume its maximum capacity with them in a very short time. Thus, unless there is a complete removal of the fish, the coarse fish continue to be troublesome.

Until good results are well established with fishing gear, partial or selective poisoning or any other method in our type of waters, we shall continue to aim in practice at a complete kill of all the fish and at restocking the lakes thereafter with speckled trout.

To date, this has proved the only reliable way, and the only one which has given really good results. Some biologists such as Miller (1950), Solman (1950), Tompkins and Mullan (1958) have expressed doubts about the complete kill of fish with Rotenone which has been claimed by other biologists. In the Province of Quebec, we have treated 105 lakes, and we must admit that at the beginning we had some difficulty in securing a complete kill, especially in small muddy ponds with floating islands containing catfish or killifish, but since then, we have improved our methods of application, and we have been able to kill all the fish in any type of lake. Lakes on private properties have been free of coarse fish for more than 10 years. However, many public lakes have been reinfested with coarse fish brought by fishermen, and people are inclined to state that the operation was unsuccessful when in fact there was no failure of the operation itself.

It is not our intention to present in detail the history of fish-toxicants and the methods of their application as well as the results obtained, since exactly ten years ago, in this same room, a symposium on the same subject was held and some excellent papers were presented. One has only to refer to the Canadian Fish Culturist, Number 8, October 1950, to find: "The History and Use of Fish Poisons in the United States" by V. E. F. Solman; "The Use of Poisons to Control Undesirable Fish in Canadian Fresh Waters" by M. W. Smith, and "A Critique of the Need and Use of Poisons in Fisheries Research and Management" by R. Miller. Since our basic methods are quite similar to those already described by these authors, we do not intend to repeat them here. We shall therefore give a description of our methods, as briefly as possible, and give a more extended treatment only to new or controversial aspects, which are numerous in laboratory work and in the field.

Toxicants Used

First, let us give a brief description of the four toxicants used, their composition and a short history of their use as fish toxicants: Rotenone, Toxaphene, Endrin and Thiodan.

1. *Rotenone*. Rotenone is an organic compound, $C_{23}H_{22}O_6$, found in the roots of various Leguminosae, marketed under the name of Derris or Cube Root, and used by Indians in South America for catching fish from time immemorial. It was obtained in a crystalline form by Greshoff (1898). Gersdorff (1930) used Rotenone for testing goldfish, using these as biological test animals for determining the concentration of chemical products. According to Krumholz (1948), Carl Hubbs was the first to suggest the use of Rotenone for the rehabilitation of two small lakes in Michigan in 1934, done under the supervision of Milton B. Trautman. Since then, hundreds of lakes have been treated with it in the United States and Canada. In Nova Scotia, M'Gonigle and Smith (1938) cleaned out 25 miles of stream and a small lake. Leonard (1938) and Vestal (1942) published an extensive paper on the use of Rotenone. In 1942 we started to use Rotenone in the Province of Quebec. Most of our supply of Rotenone comes directly from South America. It is supplied in the form of a powder, Cube or Derris Root, whose concentration in Rotenone may vary from 5% to 8%. We generally use a product with a concentration of 7.1%. We also use Rotenone in liquid form with an emulsifier, the concentration of that product being usually 5%. The concentrations generally used in our waters vary from 0.5 p.p.m. to 3 p.p.m. of Derris Root at 5% Rotenone, and are as follows for the different species concerned: 0.5 to 0.7 p.p.m. for perch, sunfish and minnows; 0.7 p.p.m. to 1 p.p.m. for suckers, ling and pike; 1 p.p.m. to 3 p.p.m. for catfish and killifish. A shallow and muddy lake demands a higher concentration than a clear and deep lake, especially when catfish or killifish are present.

2. *Toxaphene*. Toxaphene is the trade name for chlorinated camphene, and its formula is: Octochlorocamphene $C_{10}H_{10}Cl_8$. Its chemical structure is uncertain; it is a mixture of isomers. It was synthesised by Hercules Powder Co. in 1945 and patented (Anonymous 1951). It is used in liquid form with an emulsifier, the concentration in active product being 61 per cent. It was used for the first time in the laboratory as a fish killer by Surber (1948) who found that a concentration of 0.02 p.p.m. was lethal to golden shiner. Since then, Toxaphene has been tested in the laboratory by Lawrence (1950) and in a lake, August 1951, by Hemphill (1954). In Canada, since 1956, Stringer and McMynn (1958) of British Columbia have used Toxaphene in many lakes. In Quebec, we also began in 1956, after discussion of the question with Hooper and McMynn, who gave us very valuable information. The concentration we have used in our lakes is around 15 p.p.b., but we presume, under some conditions, that we could use a much weaker concentration, if there was duplication in a lake of the conditions we have in a laboratory, where we know we can kill one of the hardest fish, *Ictalurus nebulosus*, at a concentration of 2 p.p.b. However, the concentration to be used may depend on many factors and the concentrations recommended by Cooper Tox (Anonymous, 1959) seem quite correct according to our own observations. Since the concentration may vary so much—from 5 to 30 p.p.b.—with the type of lake or stream, a close examination of the local conditions is necessary. Concentrations of 17 p.p.b. and 2 p.p.b. of Toxaphene on *Ictalurus nebulosus* give practically the same pattern of curve in time-mortality, (Prevost and Grenier, 1960b) except at the beginning, and thus the impression is that there is an optimum concentration and that the use of a strong concentration does not yield better results for extermination. We may here point out that Toxaphene is, or was, contained in a commercial product called Fish-Tox, although this was not disclosed by the Company, but was discovered by McMynn and

Stringer (1958). The result of its use was that lakes remained toxic a very long time. It was found that the Toxaphene incorporated in this product was about 10 times stronger than necessary to kill fish.

3. *Endrin*. Endrin is an organic product having the formula: 1,2,3,4,10,10-hexachloro-6,7-epox-1,4,4a,5,6,7,8,8a-octahydro-1,3-endo-5,8-dimethanonaphthalene. It was discovered by Shell Oil Company (Anonymous, 1948) and tested on fish in a laboratory for the first time by James H. Stevenson (1952). We have not found anyone who has used it as a means for reclaiming lakes. However, we poisoned our first lake with Endrin in 1958, and since then a few lakes have been treated with it. The product used comes from the Shell Oil Co. Ltd, and contains 20 per cent of active material. It has been found by Henderson *et al.*, (1959) in the laboratory, to be the most toxic product for killing fish as compared with Toxaphene and other products. It is used in liquid form with an emulsifier. The concentration of the Endrin, after it is spread in the lake, is around 2 p.p.b. In the laboratory we have been able to kill catfish, 6" long, with a concentration of 0.5 p.p.b. after 48 days.

4. *Thiodan*. Thiodan is an organic product having the following formula: hexachloro-hexahydromethano-2,4,3-benzodioxathiepin oxide, as described by Niagara Chemical Division (1958). It was synthesised by Frensch, Goebel, Finkenbrink and Staudermann (1954). The first tests with fish were performed by Prof. Lendle, (1956) Institute of Pharmacology, University of Goettingen, and a report of 29 pages was presented on July 16, 1956, to Hoechst Co. It is unfortunate that this work has not been published so that better credit could be given to Prof. Lendle. The first published paper is from Prof. Adlung *et al.* (1957). Another paper was published by Adlung (1957) on the influence of temperature. According to Les Veaux (1959) the Plant Pest Control in the U.S.A., in 1958, performed some small scale tests in the Adirondacks in a small pond. But this was simply to test this insecticide for agricultural purposes by observing its effect on fish. Also, Cole Wilde reported verbally that in 1959 he treated Mohawk Pond for rehabilitation purposes, and killed all the fish, even killifish, with a concentration of 46 p.p.b. Last October, we treated a lake with Thiodan, using a concentration of 2 p.p.b. and we shall know the results next spring. In the meantime, we are conducting laboratory experiments and we have been able to kill *Ictalurus nebulosus*, six inches long, with a concentration of 0.5 p.p.b. after 84 days (Prévost et Grenier, 1960b).

Laboratory Experiments

General procedure. It is normal to try any poison in the laboratory before trying it in a lake. This does not mean, however, that the results in the laboratory will duplicate those found in a lake, and very often results, even of experiments in the laboratory, do not repeat exactly, because there are so many variables which workers sometimes overlook or which they cannot overcome.

In the field of aquatic pollution, fish is the most frequently employed test organism. Standard methods for bioassay and accurate statistical interpretation have also been worked out and the excellent contribution of Doudoroff *et al.* (1951) is the bible on which we may rely for bioassay work, especially with industrial pollutants of generally high concentration of toxic material. However, these authors point out that "details of methods for the detection and study of chronic toxicity are not within the scope of

the present recommendations" and the results obtained by their method, therefore, "do not represent concentrations which may be harmless in fish habitats subject to pollution".

We must therefore consider the use of this method with a very critical eye and try to improve it. While obtaining very interesting knowledge on the effect of Toxaphene on fish, we hope also, by our experimental methods, to help to improve the bioassay methods actually in use and contribute to a standardization of them. The great necessity of this has been pointed out by many workers.

We must remember that the bioassay methods have been worked out with a view to preventing pollution, not to killing all the fish in a lake, as we have to do. On the other hand we must also, in some cases, prevent the killing of fish in effluents of the lake. Our methods will therefore necessarily be different. Nevertheless, we shall occasionally use Doudoroff methods simply to show that in general they do not work for the type of information we need, and thereby caution other workers.

Our methods will vary with the type of information we seek and in our case this information may be three-fold.

1. Information concerning the effect of pure organic compounds or other compounds, on fish placed in well-defined laboratory conditions. This we would call *fundamental information*. The experiments have thus to be conducted in such a way that they can be comparable anywhere they are performed. This is the most difficult task we have to undertake, but it is what we should aim at, if we want good comparable results.

2. Information concerning the influence of pure organic compounds or other compounds, on fish of a precise locality. Although there are many factors to keep in account, we can obtain this information rather more easily than information of the preceding category.

3. Information concerning the disappearance of toxicity in a body of water. This information is the easiest to obtain, though some important factors have to be taken into account in our procedure.

It is not our purpose here to describe the standard method which, in our opinion, should be used for each kind of information desired, since this is published in another paper (Prévost, 1960b), but the experiments performed with these toxicants and the results obtained will stress the importance of a standard method and of all the numerous factors we have to take into account.

Here are some examples of these:

Source of the Fish. Speckled trout of same strain, same weight, but of different length and from two different hatcheries, and fed differently, one with mostly a meat diet, the other with dry food, show a great difference in resistance to Toxaphene (Leduc and Prévost, 1959b). Both groups were submitted to a concentration of 0.00296 p.p.m. of Toxaphene at five degrees Centigrade. With the group from Baldwin's Hatchery where a diet poor in meat was given, the fish start to die after 4 days, while the fish from the St. Faustin group, with a richer diet in meat, start to die only 14 days later when 60 per cent of the other group have already died. The interval between the two curves is sufficiently great to remove all doubt. The experiment shows also that the bioassay technique such as recommended by Doudoroff *et al.* would not show any

mortality and so would be inappropriate. We must mention that we had comparable results on using Toxaphene at higher concentrations, say 0.0048 and 0.0148 p.p.m. The interval was, of course, narrower in this case. Thus, an experimenter is only deceiving himself if he thinks that by using specimens of a species of fish, of a certain size, from one source, his results could be compared to those of another experimenter of another district who used the same species of fish, of the same size, but from a different source. But keeping a record of the whole history of the fish would help him to understand the difference between the results. He might then be able to explain some divergence, as we think we are able to do in this case. Although Toxaphene metabolism in fat tissues is not yet established, fat content of the body seems to be a limiting factor of intoxication as a result of its liposolubility (Anonymous 1952, Metcalf 1955). The greater resistance of the St. Faustin trout to Toxaphene could be explained by a weight relatively higher for their length than those of Baldwin Mills, probably owing to a larger fat deposit caused by a meat diet as compared to a dry diet.

Size and Ontogenesis. It has been demonstrated many times that a big fish would resist toxicants better than a small fish of same species. We should consequently suspect that a young vesiculated fry should be less resistant than a 6-inch-fish. But Steinmann (1927) showed that trout fry prior to the resorption of the yolk sac are less sensitive than the adult animals. Fujiya (1955) showed that the fertilized egg of carp is more resistant to Endrin than the fry at five days, three weeks, six weeks and three months after hatching, and Iyatomi Kisabu *et al.* (1958) have shown that the median tolerance limit for a carp of one day after hatching is 180 times greater than after six days at a temperature of 20°C. In using Toxaphene at a concentration of 0.740 p.p.m. on speckled trout, we found (Leduc et Prévost, 1959b) that sensitivity rises following the embryological development. At four and five weeks old, mortality is nil after 170 hours, but reaches 100 per cent at 10 weeks old, after 20 hours. The increasing sensitivity following the development is understandable when we look to the fat content as a limiting factor of intoxication with Toxaphene; a brief round-up of the literature concerned with biochemical changes during ontogenesis shows that fat is mainly utilized at the end of the sac-fry stage (Phillips and Dumas, 1959). Metabolism of fat could then explain the difference of sensitivity to Toxaphene in our experiments. This shows that if we require sensitive fish, we should use specimens not less than 10 weeks old, and since the one-year trout is fairly close to the 10-week fry, as far as sensitivity is concerned, it would seem a desirable fish for long-term experiments.

Duration of the Experiment and Symptoms. In the bioassay methods described by Doudoroff *et al.* (1951) for checking the toxicity for mortality tolerance limit, time was established at 24, 48 and 96 hours, and occasionally eight days, but later on Doudoroff, Katz and Tarzwell (1953) revised these methods and suggested 10 days. They state also that "very pronounced distress and persistent loss of equilibrium (turning over)" would be a sufficient criterion. But we do not agree on these points, as fish can begin to exhibit symptoms after a much longer time than 10 days. For example, a catfish died only after 84 days' exposure to a concentration of 0.2 p.p.b. of Thiodan, and *Semotilus atromaculatus*, exposed to one p.p.b. of Thiodan, turned over after 8 days and remained like that for six days. When put back in fresh water, it regained its equilibrium within 24 hours. It follows from this that death must be the criterion used in our experiments, if we do not wish to be led astray in actual poisoning of natural waters.

Volume of Solution. These results alone show that we have to be very careful in our assumptions, especially when we wish to know the concentration which will kill all the fish, not only 50 per cent of them.

It is, therefore, very important to determine the volume of solution to be used when we operate in still water. According to Doudoroff *et al.* (1951), we should use not less than one liter per gram of fish and not less than one liter per fish. However, Doudoroff, Katz and Tarzwell (1953) modified their method, in the light of our work (Prévost, Lanouette and Grenier, 1948) showing that decrease of toxicity in a small volume of water might impair the results of the experiment. They found that with Toxaphene one liter per gram of fish was insufficient and they suggested five liters. This apparently was decided empirically since no experiment is mentioned to show that it was the correct amount of solution to be used. No doubt they thought this quantity was great enough to produce any effect that was due to appear. For the concentration used, they had the expected results, but for the kind of information we need in our work it would not be satisfactory, as demonstrated by the following experiments (Leduc and Prévost, 1959a):

Speckled trout (*Salvelinus fontinalis*) placed in a concentration of 0.0285 p.p.m. of Toxaphene show different results: if they are placed in a volume of 0.83 liter for each gram of fish no mortality occurs, but if they are placed in a volume of 1.66 liter per gram, 50 per cent die, and in five liters, mortality is still higher, say 85 per cent.

This shows very clearly that one liter per gram of fish, which is the general standard admitted for testing poison, would not be acceptable for the kind of knowledge we wish to have, since what we have in view is to find the minimum concentration of a poison which would kill all the fish. It follows that if we had used a weaker concentration, it would have been still more obvious that the ordinary recommended volume of one liter per gram of fish is insufficient. Even five liters do not suffice.

However, if we have to operate in a restricted volume of water, we must first test it in different volumes, taking account of the species of fish, its size, and other factors such as temperature, etc., and establish the minimum volume necessary. Although this method is the only scientific one for determining the correct volume of solution to use, we can rely on another one which consists of using what we estimate to be an excess of solution, and repeating the test in the same solution (Hooper *et al.*, 1955). If the results are not the same or nearly the same as in the first test, we increase the volume of the solution and start all over again. Waste products from the fish might affect the fish themselves and might then act similarly to the poison of the solution, and on the other hand, a diminution of the toxicity could result from the absorption of the poison and its elimination by its breakdown in the organism. Again, if the fish survives a longer time in the already used solution, this does not necessarily mean that the concentration of the poison has decreased accordingly but that the secretions of the fish may have produced a better habitat. In fact, it has been demonstrated by Allee *et al.*, (1934) that there is an optimum habitat for fish, which is not necessarily represented by pure water. It has been proved, in general, that fish thrive in water containing a certain quantity of substances produced by the fish themselves, this water being then called conditioned water. Thus, under some circumstances, chemical analysis of the water might be desirable to give a better evaluation of the effect of the poison used.

Instead of using a great volume of water, we can change it as often as necessary, and wherever possible, it is better to have a constant flowing solution in quantity

great enough that similar results would be given by using two aquaria in succession, the second one receiving the solution from the first. Some mechanical devices for dispersing the product in water can be found on the market, but there is a very simple device developed by Grenier of the Quebec Biological Bureau (1960) using the principle of the Mariotte Bottle. This system delivers a constant flow of a constant concentration. The temperature of the water is kept constant through a cold unit system and an automatic valve to supply warmer water if desired. The temperature is constantly recorded on a micromax and the variation is less than 0.2 degrees Centigrade. This arrangement allows us to pursue experiments month after month, and would be very valuable for bioassays in pollution work also, if we wished to detect a chronic pollution caused by minute amounts of a toxic material.

Temperature of the Water. Since metabolism increases with temperature, experiments in flowing water at 5°, 10°, 15° and 20°C were set up, using *Salvelinus fontinalis*. Leduc, Grenier and Prévost (1959) found a marked difference between 5° and 10°C, which stresses the sensitivity of the trout in that range of temperature. The threshold of sensitivity of the trout of 20 gr. has been found for a 30-day period at 5° and 10°C to be 0.00148 p.p.m. of Toxaphene. However, this is no longer valid at 15° and 20°C, where mortality reaches 40 per cent and 88 per cent respectively after 28 days.

Short periods of 96 hours as used by Henderson *et al.*, (1959) are not sufficient to define toxicity of insecticides such as Toxaphene, when used chiefly at low temperatures. In our case, observations confined to 96 hours would not indicate any effect of Toxaphene below 0.0029 p.p.m., while 100 per cent mortality is obtained when the experiments are pursued a longer time.

Natural Waters

Recalling what we said about the failure of netting or other mechanical procedures, or partial poisoning, to remove enough fish in our type of waters, we must try to kill all the undesirable fish and prevent their introduction. With the poisons mentioned, we kill trout also, since they are the most sensitive of all the fish we have to deal with. These poisons have not been found selective enough to save them, and the usual conformation of our lakes does not permit successful spot poisoning, as can be performed in other regions. Consequently trout will be killed, and will sink to the bottom of the lake like most individuals of the other species. Thus, unless the lake is very shallow and permits the viewing of the bottom, or a thorough search with "Scuba" equipment, one is unable to establish the fish population of the lake in this way as some people think, being under the impression that most, if not all of the fish, float to the surface.

Prerequisite

First we must establish that but for the coarse fish, trout would live well in a given lake and second, that coarse fish cannot reintroduce themselves naturally. We must therefore consider the upper waters and the outlet.

(1) *Upper Waters.* If there are other lakes flowing into the one we wish to poison, we have to be sure that no coarse fish are present in them. If there are any, poisoning of those lakes also should be performed. Some people think that a screen could efficiently be placed to stop fish from coming down. Although it is theoretically possible, it has rarely been efficient, since such screens are liable to break at any time, especially in

winter. They would have to be made of very small mesh to prevent small fish passing through and, in most cases, would require a great area to allow the water to flow through. But, if there is no other way, we would recommend three screens in succession, 10 feet apart, so that if one breaks it can be repaired without danger of contamination. The only sure way, however, of keeping out coarse fish from higher up, is to poison all the lakes containing them.

Outlet. It is important to know the course of the outlet. If it passes through somebody else's property or if it flows into another lake, we have to make arrangements with the owners, since toxicant will be carried downstream, and could kill fish, unless some successful means are provided to prevent this, means which at the moment are under study. This being done, we must check very carefully to find if there are any straight waterfalls of at least four feet high, anywhere in the outlet, to prevent the ascension of undesirable fish from downstream. In addition, if adjoining streams flow into the outlet before we find such a waterfall, these have to be poisoned also, or screened, as described above, and if they lead to lakes where there are coarse fish, these lakes also have to be poisoned, unless efficient screens can be installed. If there is no such waterfall, perhaps some spots can be dynamited, with a view to creating the required four-foot waterfall, or else a concrete dam can be built. A wooden dam is usually very precarious; it may deteriorate very quickly and so we do not recommend it. A beaver dam is not reliable either. Too many failures have resulted from such dams. Of course, screens are very liable to break, as mentioned for the upper waters. If a four-foot dam cannot be built, but only a two-foot one, fish can still be prevented from going up a stream by placing two rows of horizontal screens below the dam over the level of the water (Prévost, 1960). If a fish tries to jump, it will hit the iron bars; it cannot go through two rows and even one row might be enough. If it is demonstrated that many fish, after restocking, come downstream, this can be prevented by building a horizontal screen on the front of the dam (Prévost, 1960). This kind of screen does not block very easily with leaves, branches, etc., and the area can be enlarged as much as is necessary.

It has been written quite often that birds transport fish or eggs from one lake to another, and some people assume from this that a lake will be reinfested. Though this may happen in the tropical countries, it does not appear to happen here, since we have many virgin lakes, i.e., lakes without a single fish, and there is one particular lake, poisoned 14 years ago, which has had no re-introduction of coarse fish. These observations, I think, prove better than anything else that in our area at least, birds count, I would say, for very little, if at all, in the dissemination of fish. Thus, the only other possible reintroduction of coarse fish is by man, and this unfortunately happens too often. We had to poison a lake three times, because after the treatment perch was introduced by fishermen. It was particularly sad in one case, because some fishermen said that the biologists were simply crazy to kill all the minnows. Trout need minnows to grow (they said) and so they reintroduced them. But this of course was 15 years ago. Now, the rehabilitation programme is well understood, and we do not expect anyone to have such backward ideas. This does not mean that minnows will not be reintroduced accidentally by people fishing with them, even though in some districts there is a complete ban on the use of minnows.

Application of the toxicant in natural waters

(A) In still waters, such as lakes, ponds

(a) General Procedure

(1) *Open drum + Gasoline pump + Outboard motor.* This is the most common type of equipment we use, because it can ensure good dissemination of all kinds of products, such as Rotenone in powder or liquid form, Toxaphene, Endrin and Thiodan. In principle, it consists of a 40-gallon drum resting on a platform, which is laid on two row boats. At the bottom of the drum, a two-inch opening is provided, and on the outside there is a valve to regulate the flow we require. On each side of this valve two pipes, about five feet long, convey the solution to each side of the boats. Although perforated pipes are not absolutely necessary, they provide faster diffusion. To have continuous operation, a pump, pouring about 30 gallons of water per minute, mixes the toxicant in the drum. The toxicant itself, if it is in powder form, is placed from time to time in the drum by the operator, at the concentration judged sufficient for the conditions we have to encounter, and is mixed with a paddle or a stick. If it is in liquid form, it can be poured continuously at a speed calculated so that good dissemination of the product will be ensured all over the lake.

(2) *Loose knitted bag.* Rotenone in powder form is placed in a coarse knitted bag such as the ordinary potato bag, which is towed behind a boat, so that the powder escapes slowly. It may need to be tapped from time to time with a paddle to help the escaping of the powder. This method, although slow, is very practical in small remote lakes when minimum equipment is desirable.

(3) *Direct from the original container.* Some materials such as Endrin and Thiodan, and liquid Rotenone, can be spread directly over the lake without having to be pre mixed with water. Toxaphene cannot be applied with efficiency in this way, because it will sink, unless it is dropped in the wake of an outboard motor. Rotenone in powder form, less miscible except with a wetting agent, will float, and mixes very little with water. These procedures are the basic ones but very often we have to use supplementary methods, which vary with the conditions we encounter in the treatment of a lake. Thus, we look to see if any of the following conditions are present and use the appropriate methods.

(b) Factors to be considered in poisoning a lake

(1) *Thermocline.* It has been demonstrated that the thermocline stops the descent of many kinds of material, and so if we perform poisoning in summertime we have to be sure that there is no thermocline, or if there is we must take steps to cross through it. But since most of the lakes have a thermocline, we perform our poisoning in the fall when the thermocline has disappeared, and in this way we are sure that poison will spread all through the lake. Although poisoning could be done in the spring with presumably the same good results, we have not tried it yet.

(2) *Weed beds* which cannot be easily reached by boat have to be thoroughly sprayed with a concentration at least three times as strong, because much of the material can stay on the emergent weeds, and not reach the water. A thorough coverage is therefore necessary. Plane-spraying does not give good results in such areas, as could

be expected, because the fine drops of liquid stay on the emergent weeds and there is also some evaporation on the way down. The liquid has to be forced through the weeds if good results are to be expected.

(3) *Floating Islands*. Poison has to be forced under these. A gasoline pump is very useful for this. Holes can be made through the floating ground at about 50-foot intervals, and a hose inserted. Sometimes dynamite placed under the islands will help to mix the poison with the water and distribute it into all the corners.

(4) *Springs at the bottom*. If these springs are of considerable size, it is advisable to locate them with "Scuba" equipment, because we have to place the poison there in good quantity, and in a continuous flow for a time, since it will be driven away very quickly. Rotenone is still the best product to use under such circumstances, since it has a very rapid action; the others might not be effective unless they are poured a long time. Such a conformation, however, is not found very often in our lakes, and is bound to arise mostly when small artificial lakes are dammed up and the source of the spring is then covered by the water of the lake. To reach a spring of this kind the best method is to lower the level of the lake, when possible.

(5) *Mud bottom*. It has been observed, in some instances, that toxicants have a diminished action in shallow muddy lakes, and in such a case, if catfish are present, we usually put (at least for Rotenone) a concentration three times as strong, say three p.p.m. of five per cent Rotenone of Cube Root. For the other toxicants we have had no experience yet of this factor, but we presume that the same procedure should be followed.

(6) *Temperature of the water*. Although a low temperature delays the action of these toxicants, a complete kill can be achieved if the proper concentration is used, even at 33°F.

(7) *Turbidity*. As our lakes are quite clear (Secchi disk readings from 7 feet to 20 feet) we have not had to consider this factor with Rotenone, although we might have to take turbidity into account with the other products.

(8) *Alkalinity of the water*. In general, alkalinity of our water is low, generally not more than 10, and so this cannot contribute to lowering the efficiency of these products (Hemphill, 1954; Hooper, 1955) as has happened in other regions, where alkalinity can be 200 and more, making it very difficult to poison lakes, especially with Rotenone.

(9) *Other factors*. As we go along, it is quite possible that we shall find more factors affecting the toxicity of these products; for example: light, chemical composition of the water, etc.

(B) *Application of toxicants in streams*

The streams are the most difficult areas to treat, on account of their running water. The poison will not stay very long in them, and so we have to use different methods. If lower down there are lakes which we wish to poison also, they must be treated first, because if we begin with the streams, they will clear very quickly, and thereafter when the lake is treated, fish could find refuge in the now clear water of the stream.

(1) *Loose knitted bag.* For powder material, such as Cube Root, a bag can be placed in a strategic place where the current will "nibble" the powder from it. However, we must put a concentration about 10 times as great as would be necessary for the same volume of still water. The concentration is calculated to stay in a stream for a period of at least one hour.

(2) *Drum—Gasoline Motor—Pump.* This system can be used with Cube Root when big streams are involved. The equipment is installed ahead of the stream and the mixture is prepared according to the concentration we need. Toxaphene can be mixed into the stream in this way also. The time of delivery varies with the length of the stream and the concentration used. For Rotenone, the average time would be 12 hours; for the other toxicants, 24 to 48 hours with a strong concentration; with a low concentration we may have to run the toxicant for two months. Although this last method would be the best, since it kills fewer food organisms, in practice it is not easy to carry out.

(3) *Direct from the container.* By placing a valve in the opening of the original container, with an air tube inside, we can ensure a slow delivery for liquid Rotenone, Endrin, Thiodan or Toxaphene, if the solution drops in a good whirling current. Time would be set as with drum and pump system.

(4) *Briquettes.* Briquettes are the easiest method to use, as we found when using D.D.T. for killing black fly larvae, as the briquettes are easy to transport through the woods, and the concentration needed can be better adjusted (Prévost, 1948). We are still working on this to improve the efficiency of these briquettes for different conditions.

(b) Special factors to be considered

(1) *Marsh weedbed.* Many streams are crossed by beaver dams, and at these points there are areas of relatively calm water, with marsh or weed beds. It is desirable to spray these with a bush fire hand pump or any other practical device, the reservoir containing a concentration 10 to 20 times greater than the one calculated for the volume of water we have to spray, at least when Rotenone is used.

(2) *Source of the stream.* The stream must be followed very carefully, so as to be sure of not missing any small tributary which can contain fish. Sometimes a stream will disappear underground and reappear higher up or it might even develop into a small pond where a lot of coarse fish congregate, which must be destroyed.

(3) *Small isolated holes of water.* In following the stream, we may find isolated holes of water, which were connected in the springtime with the main stream, and therefore are bound to contain fish, especially if there are small springs close by. Consequently, these holes have to be sprayed. A very good way of reaching all these holes when there is a beaver dam at the top, or any other dam, is to open it and flush it. The water will then rush down, flooding all the areas alongside the stream and reaching all the holes.

(4) *Use of two kinds of toxicants.* When a lake is treated with Toxaphene, for instance, and since we know that fish can survive two months when exposed to it, this creates a problem for the streams. Since we do not want to use too strong a concentration of the chlorinated toxicants because they kill many food organisms, we wish to rely on Rotenone. But this product, being of quick action, will stay in the stream a

very short time, and so, later on, fish of the lake, although poisoned with Toxaphene, have plenty of time before they die to reach the water of the stream, which will be clear of all poison. And so they will survive. To overcome that, a screen can be installed for a period of two months at the mouth of the stream, but then if poisoning is done in the fall, as is our usual practice, the screen will be exposed to ice, and break. Even apart from ice, a screen is never a sure protection, and so the best thing to do is to poison the stream with Rotenone at the time we treat the lake with the other poison, and poison it again later on, at a moment when we are reasonably sure, after a good inspection of the lake and a netting operation, that no live fish are left in the lake, and that the lake is still toxic to fish. This is the only sure procedure to use. A good timing of these operations has to be set, otherwise reinfestation may take place.

Effects on other aquatic animals than fish.

Rotenone, according to Hamilton (1941) constricts the blood vessels of the fish and causes their death by asphyxiation. This statement, however, contradicts Scheuring and Heuschmann (1935) and Daneel (1933), who claim that respiratory function is impaired by a withering and breaking-down of the gill epithelium. At all events, Rotenone has little if any effect on other aquatic organisms when used in weak concentration, strong enough to kill fish. When we use a strong concentration to kill catfish, we might kill some micro-crustaceans. However, since their eggs are hard to kill these will assure the survival of the species (Hamilton, 1941). The chlorinated products act differently, really like a poison penetrating into the whole system of the organisms and some observations concerning their effects on aquatic organisms other than fish have been done in the laboratory and in the field.

(a) *In the laboratory*

It is very difficult to perform such experiments in a closed vessel for a certain length of time. If many organisms are present, some species may eat each other. Even alone, they could die of starvation and results would differ greatly from one experiment to another, since organisms such as insect larvae are in constant development, and therefore there is great variation in their physiology, including their resistance to poison. Nevertheless, we made some crude observations, and we give below a tentative list of organisms by order of decreasing resistance to Toxaphene in T.L.M. for a period of 24 hours (Prévost, 1959) compared with Hooper's data (1955) and Robert (1960).

9.5 p.p.m.

Ephemera simulans (Hooper)

1.5 p.p.m.

Daphnia magna (Hooper)

.7 p.p.m.

Mayflies (Prévost)

Dragonflies (Prévost)

Damselflies (Prévost)

.1 p.p.m.

Asellus intermedius (Hooper)

Backswimmers (Prévost)

.060 p.p.m.

Gammarus fasciatus (Hooper)
Gammarus (Prévost)
Hydra (Prévost)
Water beetles (Robert)
Naïas (Prévost)
Water boatman (Prévost)
Belostoma (Prévost)

.037 p.p.m.

Chironomids (Prévost)
Cladocera (Prévost)

.0075 p.p.m.

Caddisflies (Prévost)
Cladocera (Robert)

According to these data, however imperfect they may be, we are inclined to assume that in the group of organisms observed, Mayflies are the most resistant and Caddisflies are the least so. This does not mean, however, that weaker concentrations would not kill these organisms—even all of them—if they were exposed to them a longer time, as would happen in the treatment of a lake. No observation has been made with Endrin and Thiodan.

Observations

(b) *In a lake*

(1) *Quantitative*. Hooper (1955) tried to make quantitative evaluation of some organisms before and after treatment of lakes with Toxaphene, by sampling a square foot of the bottom soil with an Ekman drag. Some of the results were very strange. For instance, in one lake he found 92 Diptera before treatment and 11 months after treatment he found only three; this should lead us to believe that Toxaphene at 0.10 p.p.m. has a very bad effect on Diptera. However, in another lake, 428 Diptera were found before treatment and 916 eleven months later, which could give the impression that Toxaphene had no bad effects, and furthermore, that it may have contributed to increasing these organisms by favoring a better habitat for them. Such results can be expected, since we know so little about the interaction of ecological factors.

(2) *Qualitative test*. Stringer and McMynn (1958) did not try to make quantitative tests, suspecting, I presume, that they could not be reliable. Consequently they took many samples in the lake, where the specific organisms are bound to be found, and they checked for their disappearance and reappearance after treatment. Although this method would give more consistent data, it is not perfect. For instance, in Lady King Lake, no leeches were recorded before treatment, but some were found after treatment; Round Lake, treated with 0.03 p.p.m. of Toxaphene, showed live Daphnia after one month, but none after nine months, whereas another lake, treated with a stronger concentration, 0.10 p.p.m., showed Daphnia all the time, even nine months later. In 1959, a lake in Mt. Tremblant Park treated with Endrin at a concentration of 0.002 p.p.m. and checked eight days later, revealed that Holopedium gibberium,

the most numerous representative of the plankton fauna in that particular lake, was completely wiped out, that *Daphnia* and Copepodes and Rotifera were still present, but in decreased number (Robert, 1960). Hooper *et al.* (1955), noticed that repopulation by most groups of invertebrates was well under way by mid-summer of the year following the treatment. We found, as did Hooper *et al.*, (1955), Tanner and Hayes (1955), Stringer and McMynn (1958), that Cladocera were living in a lake which was still toxic to trout. Thus, contrary to what is stated by Hemphill (1950), the presence of live plankton is not a good index for the disappearance of toxicity in a lake to be restocked with trout. It is quite evident that Toxaphene and Endrin have a drastically bad effect on food organisms, and some of them might completely disappear. These might be an important link in the chain of food, or again they might be not indispensable. What counts of course, is the final result; good fishing with no impairing of the water. If we attain that goal, whatever happens to some organisms is of no real importance.

Verification of toxicity of the water

Most of the time it is taken for granted that the commercial product we use for killing fish contains the active element in the concentration specified, and no test is made. However, it is desirable to test the product in the laboratory with the fish we wish to kill and to see if it has the effect expected. It is particularly wise to do this with Cube or Derris powder since this material, if kept in a damp place for a certain length of time, can deteriorate. A colorimetric test, such as that described by Post (1955) could also be made. However, this is not a sufficient test. It is desirable to test the water, say two days after the treatment has taken place, to be sure that we have the right concentration. The best way would be to put fish of the same species or an even hardier species in cages (be careful of their escaping) at different spots in the lake, in surface and in depth, or to check the water in the laboratory. Nets and traps can be used, but it is as well to recall that with Toxaphene, live fish can still be caught in nets even two months later, and this is not abnormal, as the effect of this product is very slow. When Cooper Tox (Anonymous 1959) states that fish may continue to die for three weeks after treatment, this figure is too conservative. However, if, four months later, live fish are still being caught, there is a strong probability that treatment has failed and will have to be done all over again. Tests can also be made in the laboratory with fish, but great care must be devoted to the volume of the solution, as stipulated previously.

Containers of the sample water must be in glass, since other kinds of material (e.g. polythene, aluminum) may decrease the toxicity of the solution after a certain time (Prévost et Grenier, 1960 a). Before restocking, a good verification must be made, in the same way, to make sure that toxicity has disappeared. A good method is to place about 6 trout, 4" to 6" long, in a wire cage of good size (one to two cubic feet capacity) at different depths and see how they survive. The cage used, which is not cumbersome, is a collapsible one (see description, Prévost 1959a). For ease of handling, fish can be transported in a polythene bag, filled with oxygen and a small quantity of water. This bag is surrounded by another bag of the same material, containing ice cubes. This method was used by us in February 1958 and related in the newspapers at that time, when we transported live fish from Montreal to Paris for the Canadian Exhibition. The method is now used in many places, and especially by the Department of Northern

Affairs and National Resources. Water can also be brought to the laboratory and checked with fish. We now use Guppies for this, as they are small, require only a small volume of water and are easily obtainable.

With Rotenone, if fish are not dead within 72 hours, it would mean that the lake is good for restocking. With Toxaphene we have to wait a much longer time since we know that catfish (*Ictalurus nebulosus*) can survive 84 days and trout at least four weeks. It can be seen that the statement by Cooper Tox (1958), that the lake is safe when 80 per cent survival takes place within a period of two weeks, may be a dangerous one. Some biologists, in verbal discussion, have suggested the hypothesis, that even if water seems perfect for restocking, Toxaphene has not necessarily disappeared from the lake.

The basis of this hypothesis relies on Hooper's demonstration (1958) that Toxaphene adheres to particles of matter in the lake, for if these particles are swallowed by fish or other organisms eaten by fish, the latter may eventually die. This could go unnoticed because most of the trout, at least, sink to the bottom, and the result could be an appreciable reduction of the fish population, if not complete wiping-out. Although this hypothesis is rather extremist, it is worthwhile considering it until it can be refuted with facts, i.e. a good demonstration of fishing results, which no one has published yet to my knowledge. Of course, if we rely on the rapid return, as claimed by Hooper (1955) and Stringer and McMynn (1958), of bottom organisms after a treatment with Toxaphene, we would be inclined to state that those organisms, which feed on particle matters, do not seem to be affected by any residual effect of Toxaphene. We cannot, however, conclude that fish will not be affected, since it has been demonstrated that many food organisms are more resistant to Toxaphene than fish, and fish, because of their fat, could accumulate Toxaphene and could then be quite affected at a critical time. Although the probability of this hypothesis is rather remote, we should not forget it in our work.

Detoxification

With Rotenone, detoxification can be very rapid; especially in alkaline, turbid and warm water, it can be a matter of a few days. In the west, it is so rapid that all the fish cannot be killed and this is a good reason for using Toxaphene instead. But, since most of our poisoning programme is carried out in the fall, in clear acid water, toxicity may last many months, and in general, lakes are ready to receive trout in the spring, after the ice is gone. However, it is always desirable to test the water first. As far as Toxaphene is concerned, detoxification may take a longer time, especially in deep clear lakes, with small flow of water. In this case, it may be 18 months or more, and in testing the water, great care must be taken, because toxicity may not be the same at all depths; the water can be non-toxic at the surface, and still very toxic at a depth of 40 feet. We have no data yet for detoxification of lakes treated with Thiodan or Endrin. Lakes poisoned with Rotenone in the fall are generally detoxified the following spring, and then ready to receive fry.

With the chlorinated products, however, detoxification generally takes a long time and it is desirable to find a method of detoxification. Hooper (1955) has found that the contact of Toxaphene with surfaces causes a detoxification. This could explain partially at least, the more rapid detoxification of the water in a turbid lake, where the

surface of millions of particles is exposed, and it could explain also the more rapid detoxification in a stream where the Toxaphene has an opportunity of coming into friction with the bottom material. But let us remember that even if water is not toxic, toxic material may still be adhering to particle matters. Detoxification in the outlet can be very rapid if other adjacent streams flow into it below the dam or falls. This will decrease the concentration, and then may render it non-toxic for the water downstream. The dilution required will vary for the fish we wish to preserve. If it is speckled trout, the dilution has to be 10 times or more. With Toxaphene the three-to-one dilution as recommended by Cooper Tox (Anonymous 1959) is surely not enough when high concentrations of toxicants are used.

If the outlet flows into a big shallow bay of a big lake, the dilution can be so great that few if any fish will be affected. We can prevent, if necessary, the approach of the fish from the lake to the stream by installing a screen in the lake. However, the biologist is looking for some means of rapidly detoxifying the water of a lake and at the suggestion of Jean-Paul Cuerrier, chief limnologist of the Department of Northern Affairs in Ottawa, we made some laboratory tests with bentonite (Prévost et Grenier, 1959). We found that a stream of small air bubbles at a flow of 1200 ml-per-min. in a cylindrical jar of 25 cm diameter, containing 16 liters of water, could detoxify a solution of Toxaphene at a concentration of 15 p.p.b. from 50 per cent to 0 per cent with bentonite having a concentration from 10 p.p.m. to 50 p.p.m. and being in contact with the solution for eight days. The minimum time and the minimum concentration of bentonite necessary for detoxification have not been worked out yet. However, these preliminary experiments show a definite effect of the bentonite.

How would this work in a lake? We do not know yet. We know that in the laboratory, bentonite sinks to the bottom of the container, if not agitated, and then has practically no effect. If bentonite does not stay in suspension in the lake, we will have to find a way of keeping it in suspension, I suspect, by the use of a pump. If a pump is necessary, then perhaps the pumping of the mud alone could give the desired results. Mud has not shown as good results as bentonite in the laboratory experiments, but it might be cheaper in the long run. These are only ideas, which are jotted down to stimulate research in this particular field of detoxification.

Health Hazards

Since we started poisoning lakes 18 years ago, we have had no accidents. The use of powdered Rotenone may cause temporary irritation to some workers, especially to the eyes. The tongue may become sticky. With the other toxicants, more careful handling is necessary and the wearing of rubber gloves is recommended, though if any spilling occurs, a thorough washing with a detergent will remove the material. Drinking the water of the lake, though it is toxic to fish, is not harmful to mammals or humans with the concentration used. If we refer to Henderson *et al.* (1959) we notice for instance that to kill 50 per cent of fathead minnows in 96 hours, it is necessary to have a concentration of 0.0013 milligrams per liter and to kill a rat we need to inject 17.8 milligrams per kilogram. This shows very well the enormous quantity of water that a rat would have to ingurgitate before it would be affected. It could not drink so much water in its whole lifetime, and this would apply even more to human beings, unless they are more selective. Consequently, relying on these observations, there is no

danger of drinking the water of a lake treated with a weak concentration of Toxaphene, and we presume this would also hold good for Thiodan and Endrin, although no test has been made. However, each company which supplies these products gives the necessary warnings, which are usually very safe. There is no danger in eating fish killed by Rotenone and there does not seem to be any danger in eating fish killed by the other toxicants, but the companies selling the products put themselves on the safe side and do not recommend eating the fish. Let us note again that most of the dead fish sink to the bottom of the lake and decompose there, generally with no danger of contamination, unless the lake is very small. If poisoning is performed in warm weather, collection of the dead fish lying along the shore may be necessary. Otherwise a foul odour may result. However, in Quebec, since our poisoning operations are done in the fall, this problem practically does not exist.

Restocking

The number of fish to stock will vary so much with the type of lake, the food, etc., that it is no use quoting a figure. But with this procedure of poisoning and restocking, no further restocking should be necessary if there are good spawning grounds, and no pressure from over fishing. A good creel census should therefore be kept for the establishment of a sound policy of management. The increase in size varies of course with the number of fish, the natural food available, temperature of the water, volume of the water, etc.

The difference between the cost of fry and fingerlings is very great and fry should give just as good results as fingerlings when there are no other fish in the lake. When there are already adult trout in the lake, it would be better to stock the lake with fingerlings or even yearlings, though in some lakes fry could do well if proper care were taken when they are deposited in the lake, and if places are not already occupied by other fish. They would have to be placed in good sheltered places and spread all along the shores. It might take hours to perform planting of this kind. Some people have expressed doubts about the reproductive capacity of hatchery trout. It is as well to remember that hatchery fish will reproduce if they have good spawning beds. Sand is not enough; percolating water has to diffuse through it. However, it is of current opinion that the life span of hatchery trout is very short; most of them will die within three or four years. Wild trout will grow more slowly, but will become bigger, because they will live longer, presumably eight to ten years.

Fishing results

It is all very well to kill the undesirable fish and take all the necessary steps to prevent their reintroduction, but people are primarily interested in knowing the quality of fishing they can expect afterwards, and when it will be available. This will vary, of course, with the poisons used and the expenditure made.

(a) The quickest results and the most expensive procedure—With Rotenone

(1) *Without any stopping of fishing.* Poisoning of the lake in October, when fishing season is closed. Restocking with trout, 10" to 15" long, in November if the toxicity has disappeared and if not, restocking in the following spring. Then fishing can be resumed.

(2) *With a brief stopping of fishing.* Poisoning in May, and restocking with fish 10" to 15" long at the end of June, if toxicity has disappeared. Thus, fishing can be resumed in August and September. The taste of the fish may not be so good as if they were stocked in the fall, especially if they have been fed with liver.

(b) *Quick results at a reasonable cost—With Rotenone*

Fishing stopped for a year or two summers. (a) Poisoning in May with Rotenone, restocking with fry in June or fingerlings in October (more expensive). (b) Poisoning in the fall and restocking with fry in the following spring. Fish will be about six inches long in the fall and 9" to 12" the following year in the fall. This is the common practice in the Province of Quebec.

(c) *Slow results at a very low cost*

Use of Toxaphene in the spring or in the fall, and restocking with big trout or fry or fingerlings when toxicity has disappeared and food has returned in sufficient quantity. We have very little experience with this method but we presume that in general the time could vary from 1½ to 3 years, and fishing could resume in 3 years or more.

(d) *Unknown results at a very low cost*

Thiodan and Endrin. We have no data yet on the disappearance time of toxicity, or the effect of these toxicants on food organisms, and therefore we cannot state when fishing can be resumed. We know, however, that the products kill with certainty.

Conclusion

This exposé has shown most of the factors we have to deal with when we decide to poison a lake, and one can see that it is not so simple as one might think at first sight. It is not surprising that some biologists have expressed doubts on the efficiency of this method. One might wonder why we should want to use Toxaphene, Endrin or Thiodan, when it is so obvious that Rotenone is the best product to use, since it acts so quickly, does not kill food organisms, and detoxification is rapid. The only reason is the cost; these chlorinated products are so much cheaper compared to Rotenone, that even with the handicaps they present at the moment, they are worthwhile considering when we have a large body of water to treat, and with more research, we might some day overcome these handicaps. The rehabilitation of lakes through poisoning fish is the best tool at our disposal. We can achieve spectacular results in the improvement of fishing, since we know that we can provide fishing almost immediately, if we wish, by poisoning and restocking with adult fish, although the usual method consists of restocking the lake with fry and providing fishing the following year, especially when we use Rotenone. In using Toxaphene, it may take three years or more. As far as Thiodan and Endrin are concerned, however, we have no data available yet.

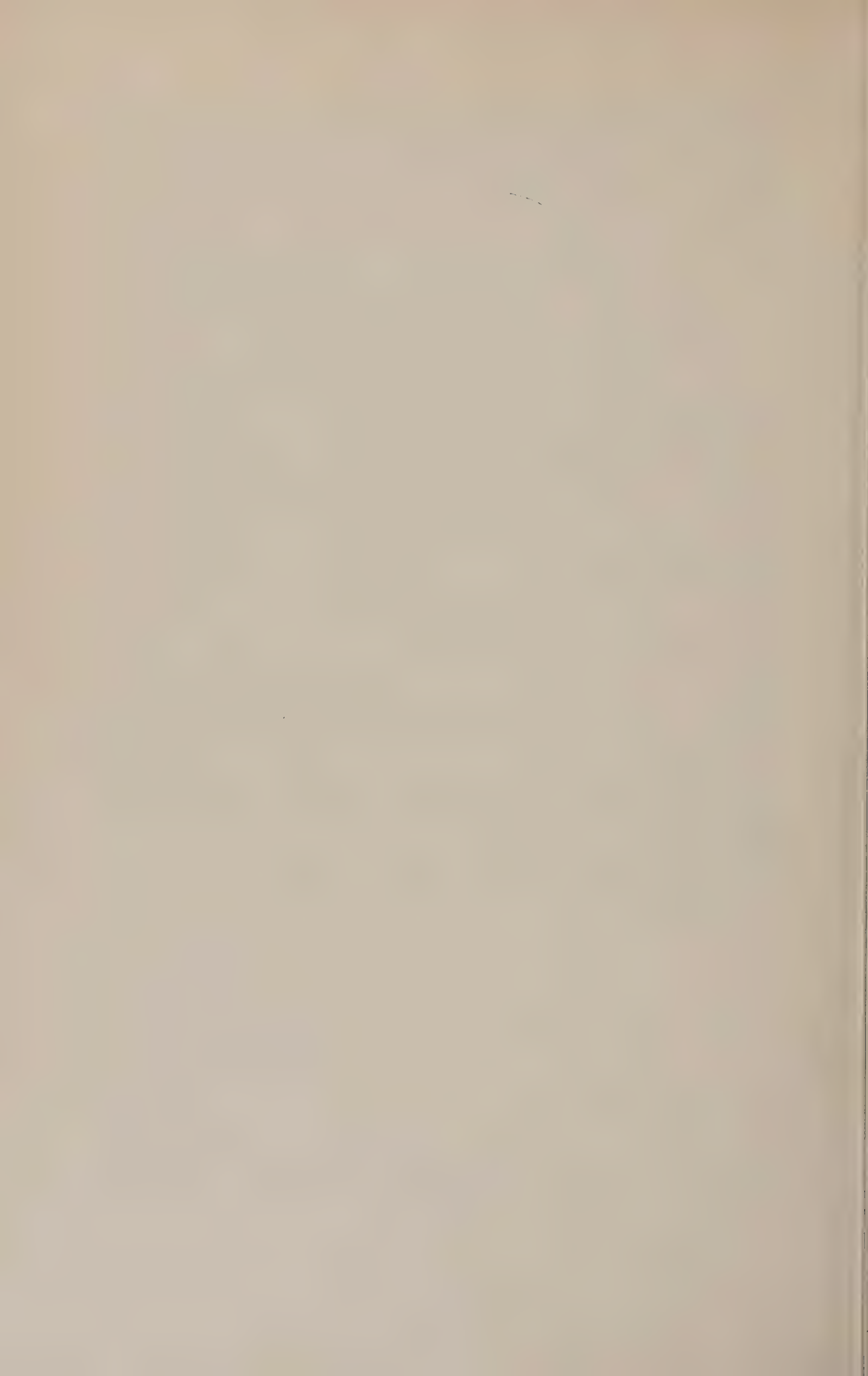
It is important to point out, finally, that the poisoning of a lake in the province of Quebec has to be carried out under the supervision of a biologist, and only after a permit has been granted by the Department of Fish and Game.

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Three Years' Use of Toxaphene as a Fish Toxicant in British Columbia

by

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Introduction

Chlorinated camphenes have been recognized for a number of years as effective fish toxins. Some of the initial results were unfavourable, due in part at least, to excessive doses. Lakes remained toxic for extended periods and much of the fauna was either reduced or eliminated. The need for an inexpensive fish toxicant stimulated an evaluation of toxaphene. Field trials in 1956 were successful and the programme was expanded in subsequent years coincident with a reduction in concentration. Toxaphene is particularly suited to British Columbia conditions. Thousands of lakes and light fishing pressure make cost of rehabilitation the limiting factor, whereas loss of a relatively small number of lakes for a few years (because of toxicity) is of lesser concern.

Methods

Original distribution gear for the toxicant consisted of a pump, flow meter and assorted attachments. These were replaced later by gravity feed from drums attached to the gunwales. In this manner chemical is dispersed via a tap and plastic hose into the propeller wash, entering the water an inch or two under the surface. This method is safe, efficient, and simple. Where small volumes of toxicant are required, water is added to the chemical to facilitate even distribution to the lake. Toxaphene is transferred from the original containers to ten-gallon drums by means of a manually operated pump delivering one quart per revolution. This procedure virtually eliminates any danger of unnecessary exposure of the operator to the chemical. All computations are based on a weight to weight basis of active ingredient.

Killing Time

Killing time is primarily a direct function of concentration. Depth and thermal stratification impede complete mixing as live fish were found in lakes a month after treatment with excessive doses, even though these lakes remained toxic for over three years (Stringer and McMynn, 1958). In a concentration of 0.1 p.p.m. Redside shiners (*Richardsonius balteatus*), hereafter termed "shiners", displayed distress symptoms in one to two hours and the majority were dead in four. In comparison, live shiners in Spallumcheen (0.005 p.p.m.), Hvas and Pinantan (0.006 p.p.m.) Lakes, although in distress, were seen for three weeks after treatment.

Reaction of fish to toxaphene has been described (Hooper, 1959) and it is noted that a large percentage die in deep water.

Plankton and Bottom Fauna

Effects of toxaphene on plankton and bottom fauna have been described (Stringer and McMynn, 1958). High concentrations eliminate most of the insect life but no appreciable insect mortality occurs at concentrations of 0.01 p.p.m. or less. Plankton was not affected at any of the concentrations used. Oligochaeta are especially tolerant (Cushing and Olive, 1956).

Amphipods are sensitive to toxaphene but less so than fish. *Gammarus* sp. and *Hyalella* sp. were not found in Alleyne Lake until 1958, two years after treatment with toxaphene at 0.01 p.p.m. As this lake is landlocked, there was probably some survival but not detected until the population increased. *Gammarus* sp. were not materially reduced in Spallumcheen Lake, 0.005 p.p.m. Tests on the latter lake, employing suspended cages, corroborated sampling data.

Summit Lake (Table I) showed a rapid increase in organisms as the water approached a non-toxic state; sampling in September, 1958, revealed a substantial population of insect larvae. In post-treatment samples, consisting of 50 six-inch Eckman dredgings taken twice annually (May and September), these larvae were the first that had been taken.

Factors Influencing Detoxification

Hooper and Grzenda (1957) describe a number of factors which influence the breakdown of toxaphene; these include light, agitation, temperature and micro-organisms. Shallow lakes, therefore, should clear rapidly. Table I shows some of the chemical and physical features of a number of toxaphene treated lakes, together with either the actual or estimated time of clearing (based on comparative survival of caged fish). Spectacle and Gallagher Lakes, both treated with 0.07 p.p.m. differ markedly in length of toxic period. By eleven months Spectacle had detoxified while Gallagher required almost three and one-half years to clear. The lakes are quite different with respect to mean depth (Spectacle 11 feet and Gallagher 34 feet) and stratification characteristics—no thermal stratification occurring in Spectacle. Taylor and Alleyne Lakes provide a similar illustration; in these lakes the main difference lies in mean depths. Detoxification of Stump Lake took place more rapidly than in many other lakes. Stump is subjected to heavy wind action and thermal stratification is not pronounced (temperature range of 63°F at surface to 50°F at 70 feet in mid August), hence, the various detoxifying agents would be more effective than in a lake which exhibited a pronounced thermocline.

Taylor and Summit Lakes, only a few yards apart, are similar in physical and chemical features but clearing times differ markedly. Taylor cleared in 12 months while the latter required four years. Here, the prolonged toxicity of Summit is obviously related to initial dose.

Ratio of annual inflow relative to total volume of a lake is an important feature in detoxification. This was demonstrated in the case of Lady King Lake and the Hyas-Pinantan chain (see Table I). For Lady King, water from the inlet creek is cooler in summer than the lake bottom water and resulted in the lower layers clearing first (Stringer and McMynn, 1958). On a large lake such as Pinaus, a small inflow will have little effect on detoxification.

TABLE I
Physical and Chemical Features of Toxaphene Treated Lakes

Name of Lake	Year Treated	Toxaphene Concentration (p.p.m.)	Area (acres)	Mean Depth (feet)	Volume (acre feet)	pH	T.D.S.	Outflow ¹ (c.f.s.)	Clearing Time (mo.) ²	
									Estimated	Actual
Lady King.....	1956	0.1	15	18	270	8.2	170	1-2		18
Summit.....	1956	0.1	12	30	360	7.9	249	—		48
Gallagher.....	1956	0.07	17	34	571	8.2	172	—		40
Spectacle.....	1956	0.07	9	11	96	8.4	285	—		11
Gladstone.....	1956	0.03	22	25	533	7.9	277	—		24
Round.....	1956	0.03	91	58	5,278	8.2	295	—		48
Taylor.....	1956	0.01	14	32	465	7.9	249	—		12
Alleyn.....	1956	0.01	135	55	7,425	8.3	308	—	48	
Hefley.....	1957	0.01	500	36	18,000	8.2	206	4		36
Dutch.....	1957	0.0075	157	46	7,222	8.0	155	—		36
Stump.....	1957	0.0075	1,928	38	73,100	—	740	—		24
Spallumcheen.....	1957	0.005	67	23	1,540	8.3	245	—		18
Hyas.....	1958	0.006	159	27	4,293	8.1	196	2	24	
Pinantan.....	1958	0.006	161	33	5,313	8.2	238	4		18
Pinaus.....	1958	0.006	417	73	30,440	—	140	5	?	
Kentucky.....	1959	0.003	108	53	5,724	8.1	232	—		

¹Estimated mean daily flow.

²Estimated clearing time based on survival of fish in cages.

Results of live cage sets indicate that a pronounced chemical stratification takes place in summer months on some lakes. Table II illustrates this point with respect to Stump and Heffley Lakes. This characteristic assumes considerable importance when evaluating the lake as being toxic or non toxic.

TABLE II

Results of live-box tests in August, 1959, for Stump and Heffley Lakes indicating evidence of chemical stratification. Cages contained 50 rainbow trout fingerlings and were set for three weeks.

Lake	Number of cages	Depth (feet)	Percentage of Survival
Stump.....	2	10	100
	2	20	95
	2	40	39
Heffley.....	2	10	52
	2	30	24
	2	40	12

Stump and Heffley Lakes were both toxic in May, 1959, as determined by live cage sets in which survival of fish averaged 40 per cent and 21 per cent respectively, *irrespective* of depth. If the evaluation in August had been based on results achieved in say the upper 20 feet of Stump, the lake would have been considered clear. It is a distinct possibility that a stocking at that time would have been unsuccessful owing to the toxic deeper layers. However, October live cage sets, following fall turn over, yielded survivals of over 80 per cent at all depths and Stump Lake was considered as being non-toxic at that time (a survival of 80 per cent or better following a three week set is the criterion used for a non-toxic condition).

Turbidity reduces effectiveness of toxaphene and accelerates breakdown. Three shallow turbid lakes (Secchi disc readings ranged from one to three feet) treated with 0.02 p.p.m. produced only partial kills. Each of these lakes contained a variety of fish species including carp (*Cyprinus carpio*), squawfish (*Ptychocheilus oregonense*), peamouth chub (*Mylocheilus caurinum*), lake chub (*Couesius plumbeus*), largescale sucker (*Catostomus macrocheilus*), fine scale sucker (*Catostomus catostomus*), sculpins (*Cottus sp.*), whitefish (*Prosopium williamsoni*), shiners, and probably others which were not sampled. Two contained largemouth bass (*Micropterus salmoides*), and sunfish (*Lepomis gibbosus*). A substantial survival of most species resulted and subsequent seine hauls yielded large numbers of fry. Post-treatment presence of shiners contrasts with results obtained in a number of transparent lakes and illustrates the decreased effectiveness of toxaphene in murky water. Laboratory tests have shown that silt suspensions have a detoxifying influence and as a result toxaphene concentrations in the order of 0.2 p.p.m. may be necessary for complete fish kills in highly turbid waters (Rose, 1958). It is suggested that toxaphene breakdown occurs by the action of micro-organisms associated with suspended materials (Hooper, 1959).

Tolerance Levels

At low concentrations of toxaphene: i.e. 0.005 p.p.m. to 0.0075 p.p.m.; fish are not similarly affected. Caged fish demonstrate marked differences in "killing time" particularly between species and various sizes. Small fish appear more sensitive, especially shiners and sculpins. This may reflect a greater sensitivity or differences in vertical distribution. For rainbow trout, laboratory tests indicate that tolerance tends to increase with size excepting alevins, which are particularly tolerant (unpublished data). Shiners do not generally sound below thirty feet but inhabit shallow water throughout most of the summer (Crossman, 1959), and would be subjected to high initial concentrations prior to complete mixing. Fukano and Hooper (1958) found that a dose of 0.005 p.p.m. killed mainly small fish. At the time of treatment of Spallumcheen Lake (0.005 p.p.m.) cages containing squawfish, peamouth chub and sculpins were suspended at various depths to augment the indigenous species of shiners and rainbow trout (*Salmo gairdneri*). Some of the squawfish and peamouth chub lived for almost three months in depths exceeding 25 feet. They were then removed due to approaching ice cover. The initial concentration in the epilimnion could account for the complete die-off in cages set in the upper 20 feet; however, sculpins were killed at all depths.

While a concentration of 0.006 p.p.m. has been used successfully for squawfish and peamouth chub this concentration has yielded only partial kills of finescale suckers in some lakes. Kentucky Lake (Table I) was treated with 0.003 p.p.m. in October, 1959, while the lake was isothermal. Indigenous species included shiners, rainbow trout and sculpins (*Cottus asper*). Five weeks later gill-nets produced a number of trout and shiners, although some dead fish could be seen on the bottom. There was no indication of any living fish in distress at that time. Since sculpins are not readily taken in gill-nets their absence may not be significant. Netting and testing with caged trout followed in May 1960. No fish were caught and tests indicate the water is still toxic. It is assumed that all fish died during the winter months.

Table III summarizes the possible lower lethal limits for a complete kill of the more common species although tabled values may still be excessive for deep and transparent lakes with negligible flushing. Clear lakes containing carp have not been treated below 0.03 p.p.m. (Stringer and McMynn, 1958) although the rapid die-off and prolonged toxicity of Round Lake suggest that lesser amounts will suffice.

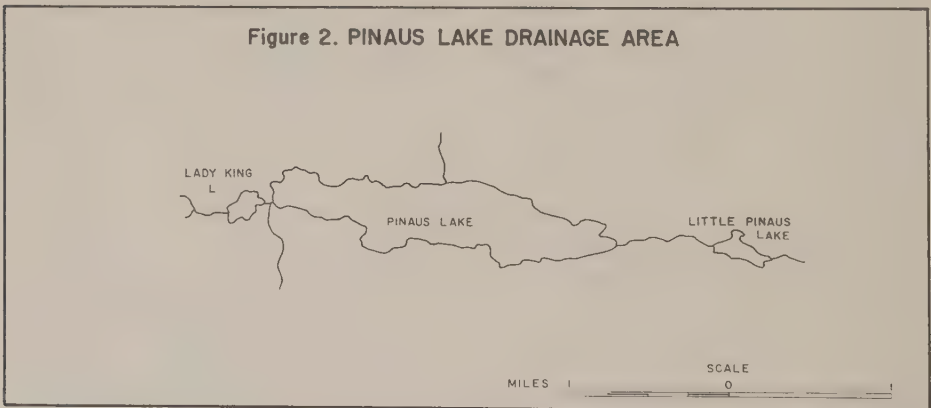
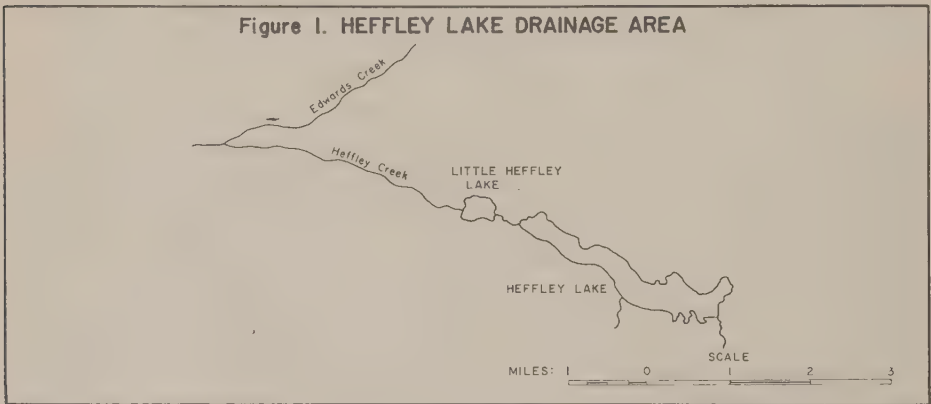
TABLE III
Possible lower lethal limit for a number of species.

Species of fish	Number lakes treated successfully	Concentration (p.p.m.)
Sculpins	1	0.003
Shiners	1	0.003
Rainbow trout	1	0.003
Peamouth chub	2	0.006
Squawfish	2	0.006
Suckers	6	0.0075

Streams

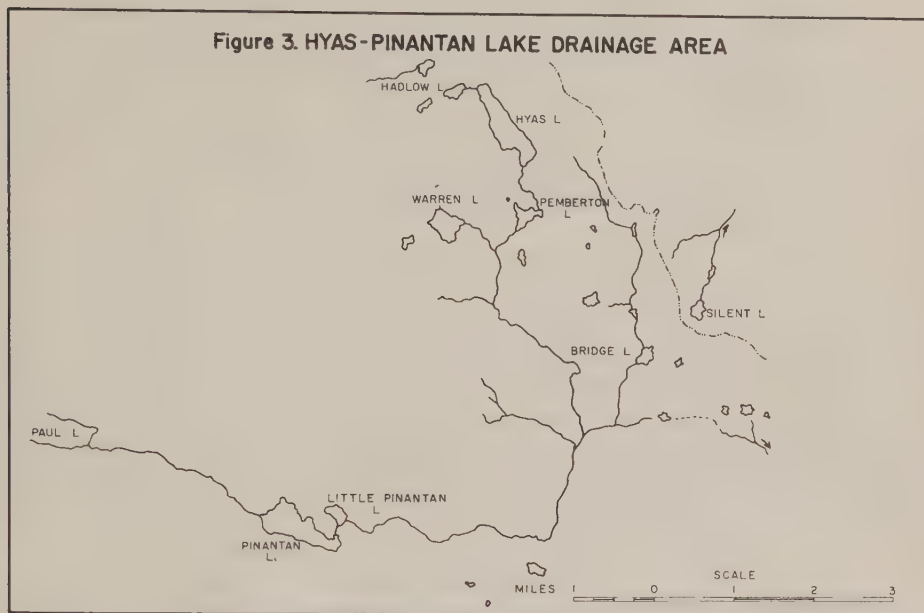
Observations of the effect of toxaphene in streams have indicated that in some instances a fish kill occurred for a considerable distance downstream immediately following treatment. This is probably due, in part at least, to an initially high concentration in the surface lake waters. However, rainbow trout have spawned successfully in outlet streams a few months following treatment of a lake.

Heffley and Pinaus are large lakes (Figures 1 and 2) each of which drains into a smaller lake a short distance downstream. These latter lakes, Little Heffley and Little Pinaus, have volumes of 340 and 210 acre feet respectively. In 1958 trout moved upstream into Little Heffley where they can now be taken, yet Heffley Lake was toxic and did not clear until 1960 (there is no appreciable inflow into Little Heffley, except from Heffley). Similarly, Little Pinaus cleared in six months even though inflow from Pinaus is sufficient to replace its volume approximately once every three weeks. Pinaus, on the other hand, was still highly toxic in October of 1959.



In December, 1959, water was collected from Pinaus creek at distances of 10 feet, $\frac{1}{2}$ and $\frac{3}{4}$ mile below the lake. Two gallons from each site were placed in aquaria along with 10 guppies (*Lebistes reticulatus*). Aquaria were sterilized at the start of the

two week test. During this interval, eight of 10 guppies died in sample collected 10 feet below lake and the remaining two live fish were in distress. There were no mortalities in the other two aquaria.



The Hyas-Pinantan system (Figure 3) was treated in 1958 with toxaphene. In June, 1959, trout fingerlings were placed into the stream two miles above and one mile below Pinantan Lake. One month later the stream, in both areas, was treated with rotenone and many of the planted trout were recovered (Pinantan and Hyas Lakes were toxic at the time). This would indicate that toxaphene breakdown is rapid in streams and corroborates laboratory findings (Hooper and Grzenda, 1957) illustrating a rapid reduction of toxicity by a gravel substrate.

Discussion

Decision as to what concentration of toxaphene should be used for a particular rehabilitation depends upon a number of factors. Species and size of fish, depth, stratification, flushing rate and turbidity all must be weighed. Although depth and stratification seem to chiefly determine the rate, wind, sunlight, and micro-organisms on the bottom affect the toxaphene breakdown. In shallow basins there is a larger percentage of contact at the mud-water interface and breakdown is more rapid under these conditions. Toxaphene in the hypolimnion probably breaks down slowly during the year as the thermocline and ice cover inhibit circulation. It would appear that the major influence on the lower strata of landlocked lakes is through mixing during the fall turn-over.

Annual run-off figures can be helpful in predicting clearing time and selection of concentration. Small lakes that flush rapidly require doses in excess of minimum because of extended "killing time" in the lower concentrations.

Treatment of turbid lakes has not been satisfactory at concentrations of 0.02 p.p.m. Although a large percentage of the fish population was killed, many fish do survive, particularly those in the larger size ranges. These partial kills illustrate differences in individual tolerances. If detoxification is rapid the more tolerant species may not be seriously affected before a sublethal level of toxaphene is reached.

Minimum dose for small fish such as shiners and sculpins approximates 0.003 p.p.m. and slightly higher for other species. Since 0.006 to 0.0075 p.p.m. may be needed for most rehabilitations, duration of toxicity for deep, clear and stratified lakes in British Columbia will be in the order of two years. When treating such lakes, it is essential to use a minimum concentration of toxaphene, or the lake will remain toxic for a prolonged period.

The toxaphene used in British Columbia is classified as a livestock spray. Viobin (Canada) Limited report the use of an emulsifier which lessens stability, apparently rapid dispersion is followed (in ten days to two weeks) by a settling of the emulsion. The toxaphene is then subject to detoxification by soil organisms. A comparison of the two mixtures would be desirable.

In streams the rapid breakdown of toxaphene is likely attributable to adsorption of chemical by gravel and sand substrate. Prevention of heavy downstream fish kills, immediately after application of toxaphene to a lake, may require the impoundment of water in order to allow time for mixing.

Acknowledgments

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Observations on the Standing Trout Populations and Experimental Plantings in Two Ontario Streams

by

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Abstract

Studies were made on two small southern Ontario trout streams representing two common but dissimilar types of streams stocked annually with hatchery-reared speckled trout. The trout population of *Stream A* was dependent entirely on these plantings. *Stream B* supported a substantial population of native trout. Standing resident trout populations at the opening of the trout season were 0.01 and 0.13 fish per yard in the respective streams. Spring plantings of yearling hatchery-reared trout increased these populations to a density of 0.02 and 0.15 trout per yard, respectively, but contributed nothing directly to the legal-sized trout population (fish 7" or over) of approximately 0.01 trout per yard in both streams.

Five plantings of advanced fingerling or yearling trout at densities of 0.01 to 0.09 fish per yard resulted in the establishment in the streams of from three per cent to 53 per cent of those trout planted. The natural over-winter repopulation of *Stream B* by trout from neighbouring waters proved more efficient in re-establishing a trout population than did an autumn planting of 200 advanced fingerling fish. The annual re-stocking policy for this stream with adequate natural reproduction was observed to be an unnecessary and perhaps harmful practice. Studies in *Streams A and B* point out the necessity of an ecological basis for fish planting programmes.

Studies in *Streams A and B* indicated that legal length limits (7" T.L. in Ontario) serve no useful purpose in the management of southern Ontario trout streams but rather may limit the potential harvest of both native and planted trout.

Introduction

This paper has been prepared in recognition of the limited data available for Ontario streams on, firstly, the standing populations of speckled trout, *Salvelinus fontinalis*, and, secondly, on the contribution which plantings of hatchery-reared trout make to standing fish populations.

Findings are reported on two common but dissimilar types of small streams occurring in agricultural southern Ontario which are stocked annually with trout reared in Government hatcheries. *Stream A* represents that type of stream lacking facilities for natural reproduction in which trout populations are dependent more-or-less entirely on plantings of hatchery-reared fish. *Stream B* is representative of that type of stream offering facilities for the natural reproduction of trout where plantings of trout, if required, serve to supplement native stocks.

Total fish populations were determined by poisoning each stream system with a five per cent rotenone derivative at a minimum concentration of two p.p.m. Hatchery-reared speckled trout used in the study were the product of the Ontario Provincial fish hatcheries and were distinctively marked by fin-clipping before release. Field assistance was provided by Conservation Officers of the Ontario Department of Lands and Forests and fisheries students of the Ontario Agricultural College. Funds provided by the Canadian National Sportsmen's Show assisted in the financial support of the study.

Description of Experimental Streams

Stream A, located in King Township, flows for a distance of approximately 4900 yards through wooded and pastured marginal agricultural land and is a small tributary of the Holland River flowing into Cook's Bay of Lake Simcoe. The stream has an average width of four feet and had a minimum flow during the study period of 4.4 c.f.s. Maximum summer water temperatures reached approximately 70°F. The polluted character of the Holland River isolates the trout population of *Stream A* from other streams of the watershed.

The stream bed is heavily sedimented, largely the result of extensive soil erosion accompanying Hurricane Hazel in 1955. The low gradient and reduced water velocity in the lower part of the stream causes a heavy deposition of silt which would seem to be the factor limiting the standing trout population to the upper 3050 yards of stream. Siltation even in this upper stream area has covered any trout spawning beds which may have been present prior to 1955 and greatly limits the carrying capacity for trout of all sizes. The fish management procedure employed for this stream in recent years was the annual spring planting of 400 yearling hatchery-reared speckled trout.

Stream B, located in Tay Township, is a small tributary of Georgian Bay flowing for approximately 2300 yards through wooded farm lands. It averages 3.5 feet in width and during the study period had a minimum summer flow of 3.5 c.f.s. Water temperatures at the mouth reach a summer maximum approximating 60°F.

In contrast to *Stream A*, the bed of this stream is relatively unsedimented and, consequently, provides good gravel spawning areas for the natural reproduction of trout and, as well, suitable habitat for the support of fry, fingerling, and larger fish over its entire length.

The annual spring planting of up to 1000 yearling speckled trout has been an accepted management technique for the stream.

Resident Trout Populations

The resident trout populations of *Streams A* and *B* were determined on April 13th and May 8th, 1957, respectively, when the streams were poisoned to determine the fate of newly-introduced hatchery trout. The term "resident trout" as used in this section excludes the newly-introduced hatchery fish.

Stream A was found to contain only 24 trout, representing a density of 0.01 trout per yard of stream, at the time of the poisoning. All of these trout were in the 9-11 inch size range, confirming the observation that environmental conditions did not favour natural reproduction. As the resident fish population was determined shortly before the opening of the trout season on May 1st, this was the maximum number of

TABLE I
Resident Trout Population in *Stream A*, April 23, 1957

LENGTH RANGE	SPECKLED TROUT POPULATION			WEIGHT OF TROUT				
	Number		Density (No. Per Yard)	Total Ounces			Pounds Per Acre	
	Native	Newly planted		For stream system (4900 yds.)	For portion of stream supporting trout (3050 yds.)		Native	Total
(T.L. in inches)					Native	Newly planted	Total	
10-11.....	1	—						
9-10.....	23	—			0.0003	—	84.0	—
7-9.....	—	—			0.008	—	—	—
5-7.....	—	29			—	0.01	31.9	2.3
1-5.....	—	—			—	—	—	—
Total.....	24	29	53	0.01	0.01	0.01	115.9	8.8

fish that would have been available to anglers on opening day. These fish weighed a total of 84 ounces and offered a standing crop of 6.5 pounds per acre available for harvest by anglers (Table I).

The resident trout population of *Stream B* differed widely from that of *Stream A*. Some 312 trout, including 11 rainbow trout, *Salmo gairdnerii*, were present in the stream and ranged in size from fingerlings to fish over 10 inches in length (Table II). This population gives a density of 0.13 trout per yard of stream of which 8.7 per cent were legal-sized fish (7-10"), 37.5 per cent in the 5-7" range, and 53.8 per cent young fish. This size composition is an excellent example of a natural population pyramid as demonstrated by the photograph in Figure 1.

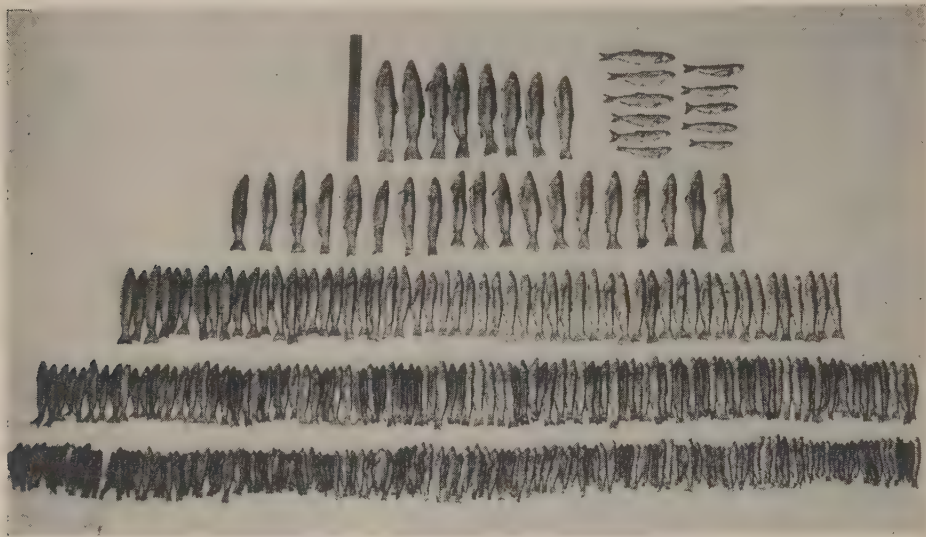


FIGURE 1.—Trout Population of Stream B. at time of May poisoning.

An appraisal of the population composition in *Stream B* shows the level of the legal-sized trout to be at a density (0.01 trout per yard) not unlike that available to anglers in *Stream A*. As the trout season had opened a week previous to the inventory, it is probable that some legal-sized fish had been removed by anglers although the stream was posted against public fishing.

In contrast to *Stream A*, adequate recruitment was present in *Stream B* with numbers of smaller fish at a density of 0.12 trout per yard of stream. As the 3-5 inch trout (53.8 per cent of the total population) were smaller than any hatchery-reared fish planted in this or neighbouring waters in recent years, these fish must be the result of natural reproduction. As no rainbow trout had been stocked in waters of the area for some years, members of this species present in the stream were the result of natural reproduction, probably by parent stock migrant from Georgian Bay.

Those trout available for immediate angling (7-10" in length) weighed 72 ounces and, therefore, afforded a potential harvest to anglers of 7.3 pounds per acre, which made up 23.9 per cent of the total weight of trout for the stream of 30.6 pounds per acre (Table III). Examination of the scales from these trout showed them to be of ages I, II, and III. The average growth rate is given in Figure 2.

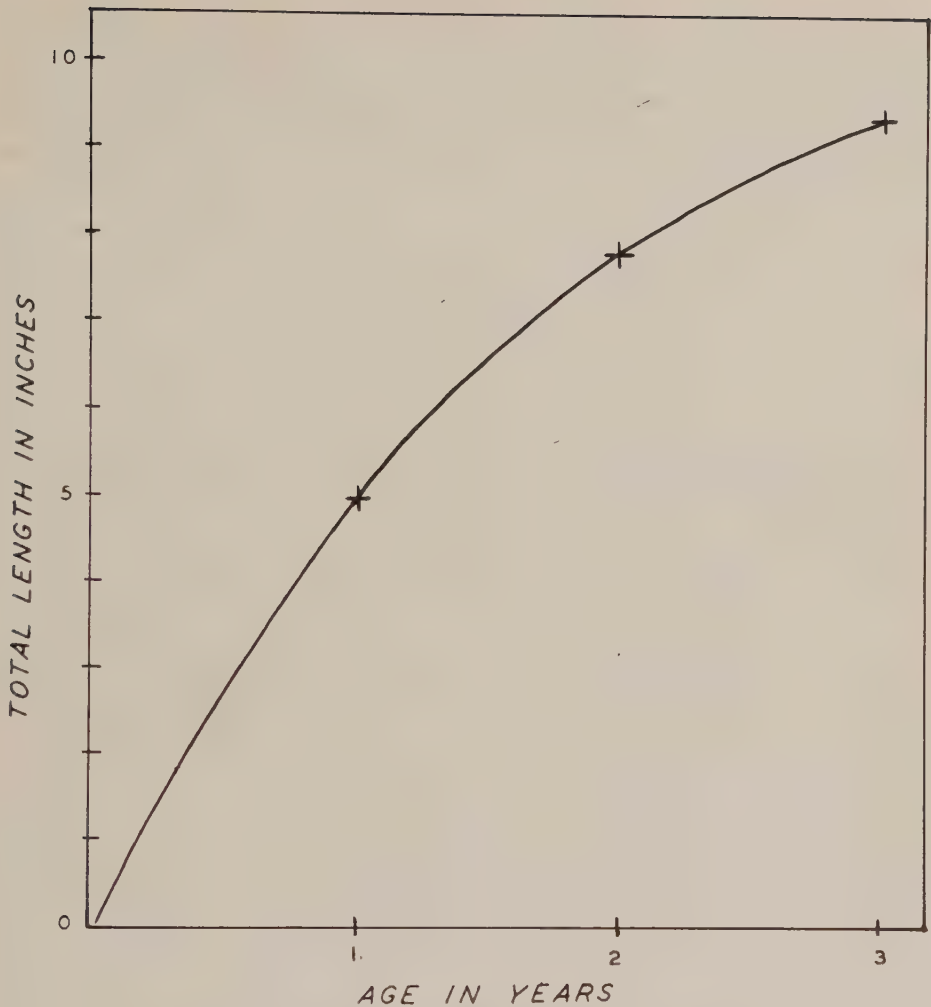


FIGURE 2.—Growth Curve of Resident Speckled Trout in Stream B.

The Results of Trout Plantings

Stream A.

Plantings of speckled trout in *Stream A* included the spring stocking of 217 yearling fish (5.7" in length) on April 16th and the autumn stocking of 200 advanced fingerlings (3.5" in length) on November 28th, 1957. Both plantings were made at a density of 0.07 fish per yard of stream. The fish were distributed uniformly over 300 yards of a mid-stream area which allowed an appraisal of the results of the plantings in terms of the number of which remained in the planted area and those which, through emigration, became established elsewhere in the stream.

The poisoning of the stream on April 23rd revealed that the planting of April 16th resulted in the establishment of 29 trout, or 13 per cent of the number planted in the stream. Four trout remained in the planted area, giving a density of 0.001 fish

per yard. Seven of the trout moved upstream to a maximum distance of 300 yards. The over-all population density of the newly-planted trout in that part of the stream found to be supporting trout (i.e. the upper 3050 yards) was 0.008 fish per yard of stream. It is of interest that this density of newly-planted fish is similar to that of the larger trout already in the stream, presumedly the result of plantings in the previous two years.

TABLE II
Resident Trout Population in *Stream B*, May 8th, 1957

LENGTH RANGE	POPULATION					DENSITY		
(T.L. in inches)	Speckled Trout			Rain-bow trout	Total	No. trout per yard of stream		
	Native	Newly planted	Total			Native	Newly planted	Total
9-10	4	—	4	—	4	0.01	—	0.01
8- 9	4	—	4	—	4			
7- 8	19	—	19	—	19			
6- 7	31	24	55	3	58	0.12	0.02	0.15
5- 6	80	29	109	3	112			
3- 5	163	0	163	5	168			
Total	301	53	354	11	365	0.13	0.02	0.15

TABLE III
Weight of Trout Resident in *Stream B*, May 8th, 1957

LENGTH RANGE	No. OF FISH	WEIGHT IN OUNCES		POUNDS PER ACRE OF STREAM		
(T.L. in inches)		Total for stream	Per yard of stream	Newly planted	Native	Total
9-10	4	13	0.01	—	7.3	7.3
8- 9	4	17	0.01			
7- 8	19	42	0.02			
6- 7	58	79	0.03	5.4	17.9	23.3
5- 6	112	105	0.05			
3- 5	168	47	0.02			
Total	365	303	0.13	5.4	25.2	30.6

The planting of November 28th proved to establish considerably fewer trout in the stream than did the spring planting. Only six trout, or 3.0 per cent of the planted fish, were recovered from the stream in the following April. These planted trout thus failed to fully utilize the suitable habitat known to be available for them by the absence of any other trout in the stream.

Stream B

Plantings of speckled trout in *Stream B* involved the uniform distribution of trout over the stream at a density ranging from 0.04 to 0.09 fish per yard of stream.

The planting of 100 yearling trout at a density of 0.04 fish per yard on May 5th, 1957 resulted in a standing population three days later of 53 newly-planted fish, or 53 per cent of the number planted (Table IV). The planting increased the population of resident trout already in the stream by 17 per cent, but contributed only to the sub-legal size group which already predominated as 90.2 per cent of the stream population. The newly-planted fish are shown together with previously resident trout population in Figure 1.

TABLE IV
Record of Plantings & Recoveries of Marked Hatchery-reared Trout

Stream	Date	Stocking Data			Recovery Data		
		Size	Number	Number -yd.	Date	Number	Percentage Survival
A	April 16/57	yearlings	217	0.07	April 23/57	29	13%
A	Nov. 28/57	fingerlings	200	0.07	April 22/58	6	3%
B	May 5/57	yearlings	100	0.04	May 8/57	53	53%
B	July 26/57	yearlings	220	0.01	Aug. 2/57	6	3%
B	Nov. 29/57	fingerlings	200	0.09	April 30/58	42	21%

A planting of 220 yearling trout (6-8" in length) was made on July 26th at which time no trout was resident in the stream. (The stream had been repoisoned two days previously and the only fish recovered were a number of rainbow trout fry which had been in the egg stage at the time of the May 8th poisoning). In order to assist in the determination of the fate of the newly-planted trout, a hoop-net was placed across the stream as close to the mouth as possible to capture any trout which might be leaving the stream.

During the 7-day interval between the times of planting and recovery, 117 of the planted trout moved into the net and, as the net was not totally efficient, it is probable that other planted trout subsequently unaccounted for passed by it into Georgian Bay. Only six of the newly-planted yearling trout, or three per cent of those planted, were recovered in the stream (Table III) and all of these were taken within 30 feet of the net. The stream above this point was barren of fish. It is of interest that the planted fish did not take advantage of the ample habitat available to them in the absence of resident trout.

An autumn planting of 200 advanced fingerlings (4-5" in length) was made on November 29th, 1957 and the stream subsequently repoisoned on April 30th of the following year. A total of 42 planted fish, or 21 per cent of the number stocked the previous autumn were present in the stream (Table IV). These trout were well distributed over the stream at a density of 0.02 trout per yard. None of the fish was of legal size to provide angling at the opening of the trout season. The most significant finding of the April poisoning was perhaps the extent of the natural repopulation of the stream with "native" (unmarked) trout from neighbouring waters.

Natural Repopulation of Streams

The natural repopulation of trout occurred only in *Stream B* where the movement of trout among the adjacent tributaries of Georgian Bay is possible except during the summer months, when warm water temperatures present a thermal barrier between the cold trout waters.

A comparison of the April stocks of trout in *Stream B* resulting from over-winter natural repopulation and the autumn planting of 200 hatchery-reared fingerlings appears in Table V. Two facts are of significance: firstly, that natural reproduction by "native" fish established a larger number of trout (speckled and rainbow combined) in the stream (0.03 fish per yard) than did the autumn planting of the 200 advanced trout fingerlings and, secondly, that the native fish were of a size range which offered immediate angling while providing smaller trout for subsequent recruitment.

This natural repopulation of *Stream B* would be expected to provide a brood stock for the coming autumn the progeny of which, coupled with probable further autumn-winter-spring migrations of trout from neighbouring waters, would utilize all niches of the trout habitat offered by the stream within a relatively short time.

TABLE V
Resident Trout Population in *Stream B*, April 30th, 1958

	Speckled trout			Rainbow trout			Total trout	
	Sub-legal (T.L. = 7' -)	Legal-sized (T.L. = 7'')	Total	Sub-legal (T.L. = 7' -)	Legal-sized (T.L. = 7'')	Total	No.	Density (No. per yd.)
Results of autumn planting of 200 yearling speckled trout.....	42	—	42	—	—	—	42	.02
Results of natural recruitment from neighbouring waters.....	26	12	38	11	9	20	58	.03
Total.....	68	12	80	11	9	20	100	.04

The failure of *Stream A* to benefit from natural repopulation may be explained by the isolation of the stream from other trout waters of the watershed by the polluted Holland River to which it is tributary. Hence the re-establishment of trout in the stream must come from plantings of hatchery-reared fish.

Discussion

The observations presented in this paper serve to point out basic differences in the management requirements of two common but ecologically dissimilar types of small southern Ontario streams. One type represented, *Stream A*, lacks facilities for natural reproduction or the support of more than small numbers of fishable-sized trout on account of excessive siltation of the stream bed. Consequently, fish stocks can be maintained only by a "put-take" stocking programme based on a reasonable knowledge, firstly, of the carrying capacity of the stream, secondly, of the rate of exploitation of trout by angling and, thirdly, of the most efficient planting procedure.

The other type, represented by *Stream B*, provides habitat conditions equally suited for both the natural reproduction and subsequent production of young trout. Plantings of hatchery-reared fish, if required, must be considered supplemental to natural reproduction.

Carrying Capacity

Although the facts presented in this paper do not attempt to provide precise data on the maximum carrying capacity, the combined population level of the established and newly-planted trout may be considered to give a reasonable indication of the approximate carrying capacity of the respective streams.

A comparison of standing trout populations in *Streams A* and *B* shows the density of legal-sized trout available for angling at the start of the fishing season to be similar at approximately 0.01 fish per yard of stream. This population in *Stream A* must be considered to be the result of previous fish plantings while that of *Stream B* may have resulted from either natural reproduction, plantings of hatchery-reared fish, or a combination of both.

Fish in *Stream A* must again be provided by plantings of hatchery-reared trout and it was shown that a spring planting of 217 yearling fish resulted in the establishment of 13 per cent of these in the stream at a density of 0.01 fish per yard. In *Stream B*, the majority of young fish were the result of natural reproduction, trout in the fingerling size-group alone making up approximately 50 per cent of the total trout population in early May.

Effectiveness of Trout Plantings

An evaluation of the results of the plantings in *Streams A* and *B* showed a considerable difference in the extent to which these fish became established in the streams, varying from three per cent to 53 per cent. Spring plantings resulted in the highest recovery of trout within each stream although the percentage survival of planted trout in *Stream A* was only 25 per cent of that in *Stream B*. The extent to which these trout established themselves would seem to be related closely to the limited amount of vacant suitable habitat available to them (i.e. under logs, undercut banks, etc.), caused in *Stream A* by heavy siltation of the bottom and in *Stream B* by a substantial resident population of trout which utilized many of the available niches.

The poorer results of the summer and autumn plantings in the two streams have not been explained although the immediate exodus of the majority of the planted trout from *Stream B* in midsummer was noted. This observation suggests that stress as described by Miller (1958) may be an important factor in the failure of the trout to establish themselves although the absence of a resident trout population made proportionately more suitable habitats available to them than at the time of the spring plantings. This available habitat in *Stream B* was readily occupied by "native" trout which subsequently immigrated into and repopulated the stream.

The percentage recovery of the planted trout in the streams does not necessarily represent the total survival of the fish for, conditions being suitable, those fish which leave the stream may survive to provide future angling in other waters. However, this was improbable in *Stream A* due to the pollution of the Holland River to which it is tributary nor in *Stream B* during the summer months where summer water tem-

peratures of the inner Georgian Bay reach 75°F or higher. The natural repopulation of *Stream B* by migrant speckled and rainbow trout entering from Georgian Bay during the winter or early spring months is proof of the movement of trout between neighbouring waters.

Hatchery-reared Trout in Stream Management

The use of plantings of hatchery-reared fish to maintain trout stocks in streams lacking any or adequate natural reproduction is a valid management procedure provided that local demand for recreational fishing justifies the operation. In streams with a low carrying capacity capable of supporting only small numbers of fishable-sized trout, such as the extreme siltation situation in *Stream A*, frequent rather than single annual plantings of yearling trout would seem to offer the best possibility for a sustained fishery. However, the effectiveness of this practice requires considerable study in view of the low and apparently variable survival of fish planted in the stream.

An appraisal of the need for planting hatchery-reared trout in streams producing and maintaining significant populations of native trout must take into account the extent to which native fish can meet the demands of the fishery. Analysis of the situation in *Stream B* at the time of the first poisoning serves to illustrate a small stream in which the reproduction of native trout provides ample small fish for subsequent recruitment into the fishable size range. The introduction of 5-7" hatchery-reared trout into the stream placed these fish in direct competition with stocks of wild trout of similar or smaller size which provided more trout than the habitat could accommodate as these fish grew. On the basis of the observations made on *Stream B*, it would seem that the planting of hatchery-reared trout in this and similar types of streams is an unnecessary and possibly harmful management procedure.

As the ecological character of the majority of small trout streams in agricultural Ontario lies within the two extreme types of streams as demonstrated by *Streams A* and *B*, the need of a restocking policy for each stream must be judged on the merits of the individual case. Stream surveys must be made to determine the approximate carrying capacity of the stream for fishable-sized trout, standing resident trout populations, and the ability of native fish stocks to provide sustained angling.

If hatchery-reared trout are deemed necessary to provide a population or to supplement native fish stocks, plantings must be made at times and in numbers which ensure the best use of these fish. Studies in *Streams A* and *B* showed a wide range in the efficiency of the plantings in contributing to resident fish stocks, varying from a low of three per cent to a high of only 53 per cent. These studies do little more than to point out the serious need for research into the effective and efficient use of the hatchery product. A look at the recent annual trout planting rates for both *Streams A* and *B* reveals that unrealistically large numbers of fish were planted which showed no relationship to the carrying capacity of the stream nor to resident trout populations living there. This may be indicative of trout planting policies in other waters.

Legal Length Limits in Trout Management

A minimum total length limit of seven inches on stream trout is a management technique employed currently in Ontario. The studies made on *Streams A* and *B* provide an opportunity to assess the value of these legal length limits in the management of these streams.

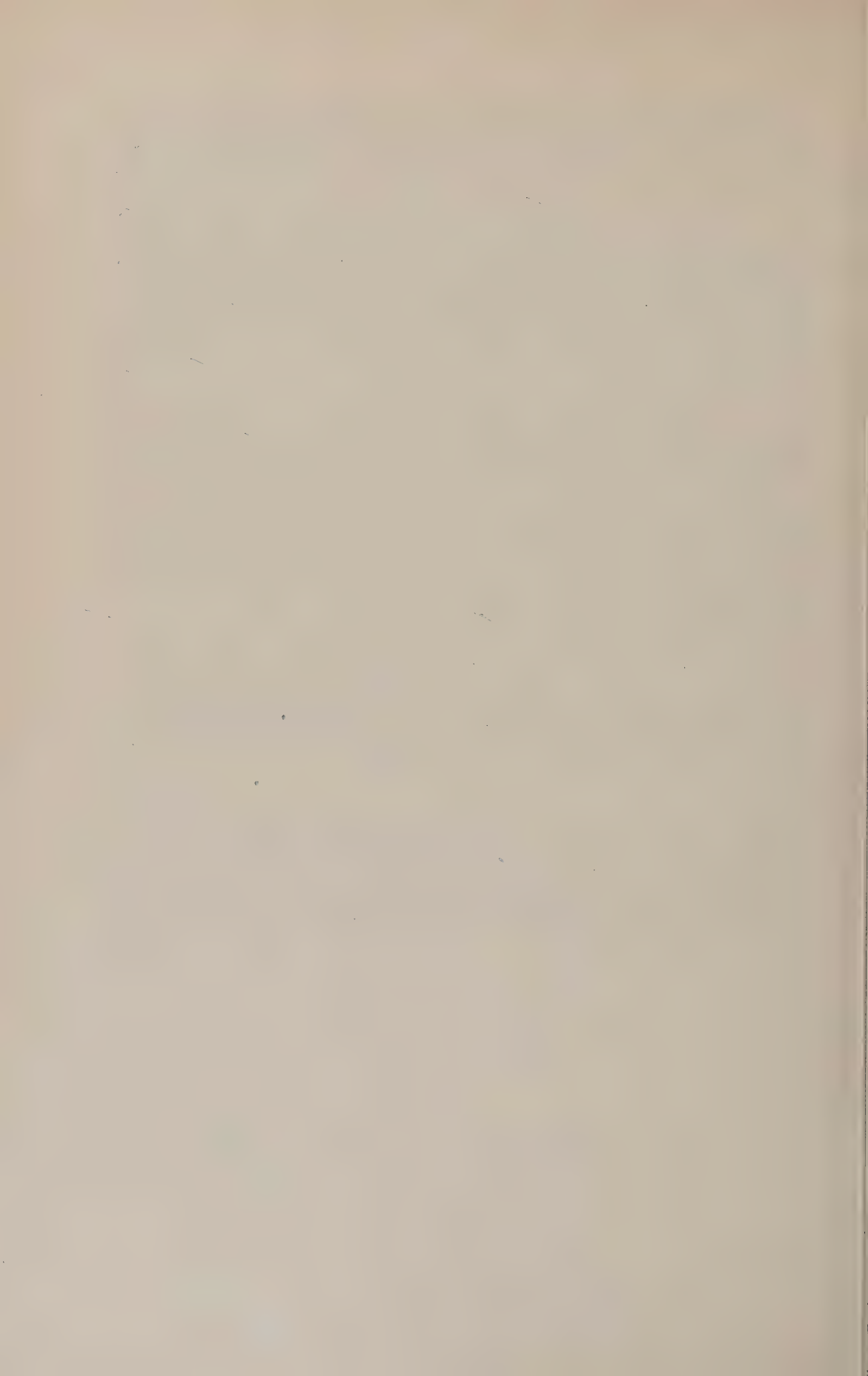
The resident trout population of *Stream A* is dependent entirely on hatchery-reared trout which are planted annually as spring yearlings on a put-take basis in the 5-7", or sub-legal, length range. Research done in the northern United States by Shelter (1949), Cooper (1952), and other workers has shown that the sooner the hatchery-reared fish are harvested after planting, the greater is the expected percentage return to anglers. As yearling trout reared in Ontario hatcheries do not usually reach an average length of seven inches by the early part of the fishing season, anglers are prevented from keeping these fish although they would form the basis of the fishery in many cases. Legal lengths in streams dependent on put-take stocking of yearling trout, therefore, would seem to serve only to limit whatever contribution hatchery-reared trout can make to fishing waters, whether or not the stream supports a native trout population.

An examination of the size composition of the native trout population in *Stream B* (Figure I) shows that the 7-inch length limit allowed a potential legal harvest of less than 10 per cent of the trout population. Some 35 per cent of the total trout population, those in the 5-7" range, were forbidden to those anglers who would be happy to catch them. Over 50 per cent of the total trout population provided a reservoir of fingerling trout for future recruitment. Hence, there is no evidence to suggest that the protection of trout below the seven inch legal limit serves any worthwhile purpose in the management of this stream but it is apparent that this regulation excluded the harvest of fishable-sized trout, many of which would be subsequently lost to the fishery before reaching the 7-inch limit.

On the basis of these observations on the trout populations of *Streams A* and *B* it may be concluded that the protection of stream trout until they reach a length of seven inches in these streams decreases the opportunity for utilization of the trout population potentially available for angling as the result of natural reproduction, the planting of hatchery-reared trout, or a combination of both. This conclusion would seem to be equally applicable to other trout streams.

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Fisheries Management Development Projects

by

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EDITOR'S NOTE: The following is an excerpt from the booklet "Lakes, Rivers and Brooks in Salzkammergut, Austria," published by the Austrian Government for the Fourteenth International Limnological Congress, August, 1959. In this booklet five scientists deal with the landscape, geology, natural history and fisheries of the Salzkammergut, a beautiful area of lakes, forests and mountains. Dr. Einsele's account of some of the fisheries management projects in Austria may be of special interest to Canadian fish culture workers.

I have always thought that a fishery biological institute does not deserve its name if it does not have a strong supporting effect on the fishery economy. Therefore I see one of our most important duties in interweaving our institute with commercial and sports fishermen. This was realized in three ways: by working together with professional fishermen of the "Gewaesserbewirtschaftung" (Fisheries Management unit); setting up an organization; teaching programme.

As far as working together in "Gewaesserbewirtschaftung" is concerned the first thing to be observed is recognition and concrete formulation of the main problems together with gaining the professional fishermen's confidence.

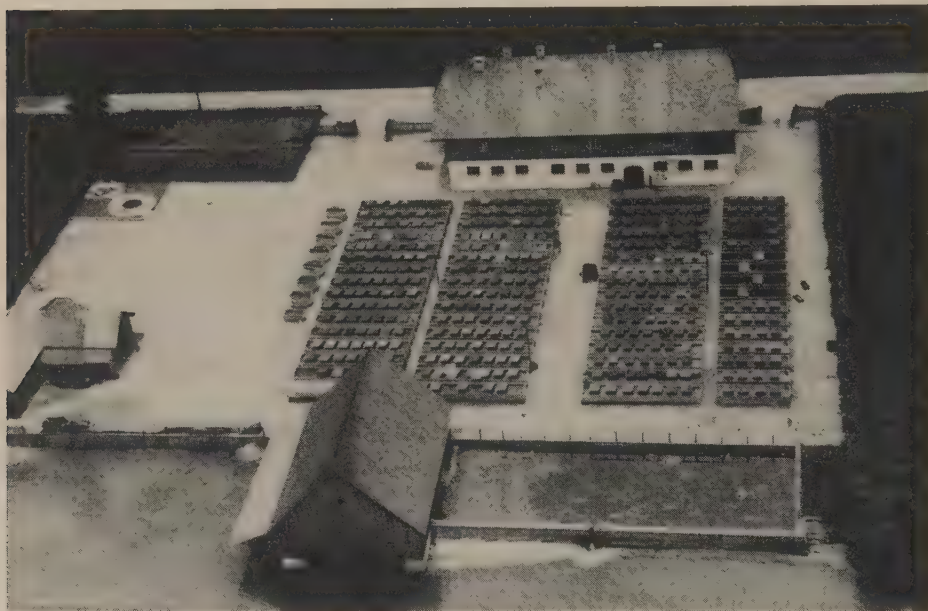
The main fisheries management problem seems to be the question: what is the relationship of available food supply to fish production, what would be the maximum ratio, and what can be done to reach a maximum harvest?

The food supply in running waters and especially in our lakes has been determined quantitatively over a long period of years. Equally intensive studies have been made of the biology of the most important usable fishes. Main consideration was given the growth rate, environmental requirements of the fry, entrance into spawning maturity, and harvesting age. The results of these studies provided the base for the first fishery management measures. For example, on "Mondsee" the size of the meshes of the gill nets for the "Grosse Schwebrenke", whitefish *Coregonus maraena*, was enlarged in one step from 42 mm. (1.6") to 50 mm. (1.95") (knot to knot); thus instead of catching four-year-old fish, five and six-year-old and older fish were caught. The average weight of the fish caught went up from 350 to 600 gms. (12 to 21 oz.) and the average number of spawned eggs was increased.

This, together with other measures, has multiplied the harvest of "Renken" in the "Mondsee" by 10 times (previously the harvest had been going down). Similar measures were applied in other lakes. I also want to mention the "Kleine Schwebrenke" (another whitefish, *Coregonus albula*) of the "Attersee" whose weight per fish was raised from 170 gms. (6 oz.) to 250 gms. (9 oz.) by mesh enlargement of the gill nets;

thus the fish reached a better marketable size. More important yet was the following: the average number of eggs per female was tripled by catching a larger sized fish which improved the natural hatching. The number of the "Kleine Schwebrenke" of the "Attersee" had gone down so much that the catches did not cover the cost. The above mentioned and other measures resulted in an excellent sustained harvest which secures the subsistence of the professional fishermen on the "Attersee".

Three things must be observed if one wishes to intervene successfully in fisheries management: to know what is the right thing to do; to get the equipment to accomplish what was recognized as the right thing; the necessary funds. The government fishery department helps in every way.



Aerial view of the Fish Culture Station at Kreuzstein, near Salzburg, Austria.

Another thing should be mentioned: 1. our investigations resulted in recognizing that the food supply in the lakes of the Alps would support much better fish harvests possible than we had so far. 2. also in our areas we have recognized that, similar to what was recognized at the Lake of Constance, the number of surviving fry is extremely small, i.e., it lies around one per thousand or lower depending on character of fry, hatching time, etc.

One of our practical tasks in the "Renken" economy was multiplication of fish of edible size by all means available. This meant to ensure increase of natural spawning and to find measures to secure better survival of the fry. Both methods were used. One was the above-mentioned increase of the size of the mesh, the other was prolonging the time of development of eggs and fry by keeping the brooding temperatures low. The first experiments of economic importance were made from 1940 to 1942 (financially sponsored by Kraftpaper factory, Lenzing). Based on knowledge gained at Lenzing

and other tests, the construction of our own institution was started immediately after the end of the war with the purpose of replacing the insufficient small brood huts on the lakes by a modern well equipped establishment. For a number of years all whitefish and brook trout rearing has been concentrated in our rearing establishments. The fry which formerly had to be planted in the lakes in January and February are now going into the waters in April and May. The small, old hatchery on the "Attersee", for example, was supplied with spring water with a temperature of 9°C (49°F). The development of brook trout eggs took only one and one-half months, that of the whitefish eggs only one month and the fry had to be planted in December or February. In our new hatchery we are able to prolong the development of the whitefish to four months. While formerly, the distribution of the fry had to be done at a time of a quantitative minimum of crustacean food, which due to full circulation were extremely hard to catch, it is done now at a time at which the zooplankton concentrates near the surface and multiplies rapidly. It is also important that the copepods, especially *Diaptomus*, which are important as nourishment for the fry, are at that time in the moulting stage (proved by experiments).

Other experiments prove that fingerling whitefish at a length of about 30 mm. (1.2") are superior to fry. Therefore rearing establishments were made which allow mass rearing. The Salzkammergut lakes now receive each year more than 500,000 such fingerlings in addition to the fry.

The rearing had very interesting scientific results. It proved, for instance, that the high egg mortality in the lakes was caused by external factors only. In rearing the losses are as a rule very low; they amount to from 0.5 per cent to a few per cent, while in nature 99.9 per cent of the eggs and young fry die.

The experimental institution of the government fishery department rears, in addition to the whitefish fry, large numbers of pike. In 1958 there were over 1,200,000. These pike are fed with *Daphnia longispina* up to a length of 5 cm. (2"). Each pike eats 70,000 to 80,000 *Daphnia* in order to reach that size, which means that the pike produced in 1958 needed not less than 100 million *Daphnias*! The rearing procedure cannot be explained here due to shortage of space.

Also mentioned above were the funds needed for the development of the fishery. These came from different sources. Large amounts were given by the U.S.A. and were carefully used by the Austrian provinces of Upper Austria and Salzburg. When the American support ended the opposite of what had been expected happened; the extent of the fisheries management programme increased steadily. Now large amounts of money are raised by liberalizing the sport fishery, especially in lake areas. Part of the money is used to supply the lakes with young fishes for the sport anglers.

A large number of young fish are planted in rivers. The supply is produced by private hatcheries; sport clubs also produce some.

It should be mentioned also that the Fisheries Institute co-operates with neighbour countries, especially West Germany, Switzerland and Holland. I should mention also that the erection of the first fish hatchery in Turkey was initiated by Austria. Austria also took the first oxygen apparatus to Turkey when transporting 20,000 walleye fry. Fish of Austrian origin are now swimming in Nioa Lake, Egridir Lake and other lakes in the Anatolian region of Turkey.

Another important branch which connects research, management and education with economic problems, is diseases of fish, treatment of sick fish and prevention of diseases. Prevention is done by hygienic measures such as disinfection of equipment, etc., and strengthening baths. Different baths play an important role in treatment. These were known earlier but were little used. This has changed thanks to our fishery schools; this way the losses of fry in some hatcheries were reduced by 50 per cent. New treatments were also developed; raising the pH of the water to a little over 10 seems to be the best way to combat fungus. Hygiene, prevention of diseases, treatment and further development of hatching procedures have resulted in diminution of brood losses. All these advances are made available immediately through our fisheries school or by individual consultations and we find that they are more and more accepted.

SUMMARY OF PROGRAMME AT THE AUSTRIAN FISH CULTURE STATION AT KREUZSTEIN (20 MI. EAST OF SALZBURG)

Directed by Dr. W. Einsele

Rearing (Late spring and summer)	Distributing (From September to end of year)	Egg Collecting (Mainly winter and spring)
Fry are fed with plankton to fingerling stage in 96 large concrete rearing tanks, circular and rectangular.	Some of the fingerlings reared in co-operation with pond culture stations.	Average annual collections
Pike 1,300,000, to 2" to 2 1/2" 2/3 exported to Netherlands, Germany and Switzerland.	Annual plantings in Austria	Whitefish eggs 40,000,000
Whitefish 600,000, some reared to 3 1/2" 90% planted in Austrian lakes.	Trout from 3"-5" 200,000	Pike..... 6,000,000
Grayling 400,000	Walleyes 4"-6" . . . 200,000	Brook trout..... 4,500,000
70% reared to 1 1/2" then sent to pond culturists who rear to 5" in fall. 30% fed to 2" or 3" and sold in Germany and Switzerland.	Trout 2 yr. old . . . 3,000 lbs.	Rainbow..... 2,500,000
"Trouts" (Char, lake trout, brook and rainbow) 400,000 as in grayling, 70% farmed out; 30% reared to 2" or 3".	Carp, young 20,000 lbs.	Lake trout..... 200,000
	Tench (tincas) . . . 5,000 lbs.	Grayling..... 500,000
		Charr..... 500,000
	These fish are assembled at the hatchery, bathed in 1.5% salt solution for one hour, sorted and sent in trucks with live tanks to various European countries, even as far as Sweden and Turkey.	

Note:

(1) Almost all these fish are fed on plankton (mainly *Daphnia*) caught in the adjacent lake (Mondsee) by 3 or more commercial fishing boats operated mainly at night for about four months. They tow a huge plankton net (6 ft. diameter x 16 ft. long) of monofilament Perlon about 125 meshes to the inch. The annual catch amounts to more than 20,000 quarts of raw plankton. (Einsele estimates that this may be only 2% of the available crop!) Some other foods are used later in season, e.g., sucker fry to pike. Cannibalism in pike, bad at 15°C. (59°F.), is much reduced at low temperature, O.K. down to 4°C. (39°F.). Raising the pH of the water to 10 for a short time kills fungus and gill disease.

(2) This fish culture station operates at a profit. Fish are provided for all of Austria's planting needs and enough additional are sold to bring a substantial income to the Government.

(Notes prepared by D. S. Rawson, August, 1959)

